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TECHNICAL REPORT ON TASK 13

CYCLOGENESIS OVER SOUTHERN EUROPEAN AND MEDITERRANEAN WATERS

PROJECT AROWA

Bureau of Aeronautics Project Arowa (TED-UNL-MA-501)
"Applied Research; Operational Weather Analysis"
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ABSTRACT

Surface cyclogenesis in the Southern European area is investigated and found to be highly dependent on the upper-air flow pattern as given by the contours at 500 millibars. Low-level tnermal fields are shown to provide a much less important contribution than they do over the United States, especially in the earlier stages. The upper-flow patterns are classified as southwesterly, northwesterly, blocking, and westerly. Cyclogenesis following the westerly pattern is catalogued, and a method for its prediction, 48 hours in advance, set forth. The composite case is illustrated along with detailed analyses of 16 recent synoptic examples. Data from 51 storms of this type from 1945 - 1951 are included.

PREFACE

Task 13, assigned to Project AROWA, requires the investigation of cyclogenesis over ocean areas. The numerous fleet activities in the Southern European waters have been responsible for the direction of the first efforts under the task to that area. This report is intended to provide insight into the recognition of the synoptic pattern which precedes the formation of major storms over the Mediterranean area.

This report was prepared at Project AROWA by Joseph J. George, Meteorologist, Eastern Air Lines, and Lieutenant Commander Paul M. Wolff, U. S. Navy. Captain F. A. Berry, U. S. Navy, Officer in Charge, Project AROWA, made many practical suggestions during the course of the study.

This research could not have been accomplished without the cooperation and assistance of many members of Project AROWA. B. V. Ianetta, AGAN, and T. M. Magnum, AG3 assisted in many phases of the investigation. The statistical computations were made by Mr. R. Haltiner. The drafting was done by W. E. Smith, AG3, and Mrs. C. Washe typed and assembled the manuscript.

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INTRODUCTION

The type of development followed in meteorological research is determined to a considerable extent by the kind of data available. In this study, the Northern Hemisphere Historical Weather Maps from 1945 through 1951 were used as a basis. These charts have been capably analyzed and printed with one surface and one 500-mb chart for each day.

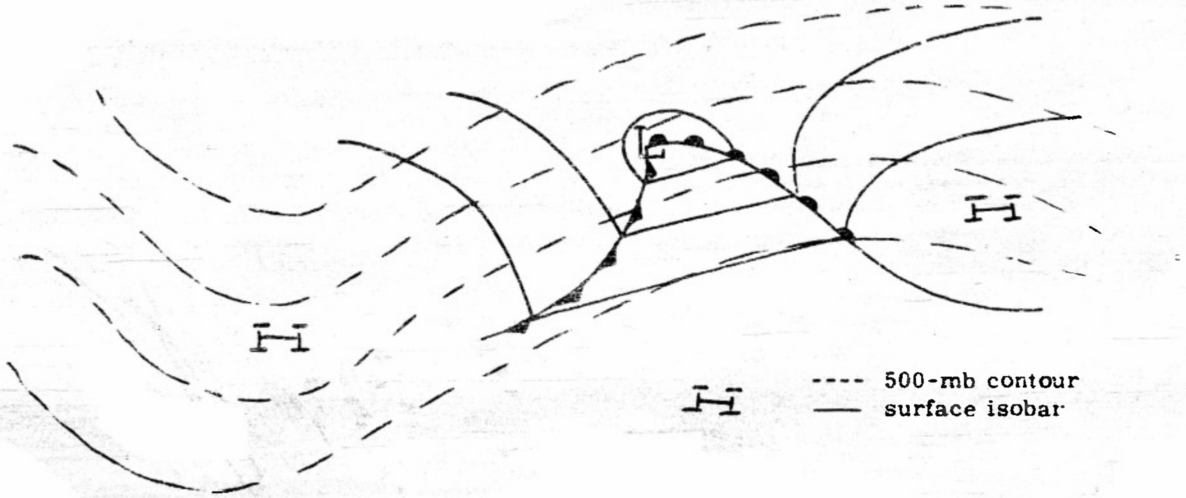
The use of charts, separated in time by 24 hours, in the study of developing phenomena, such as cyclogenesis, results in a certain basic inhomogeneity of data. That is, all storms will not be in the same stage of development on 0300Z of day one in the sequence.

The results achieved, in spite of this long interval between maps, may indicate that this type of cyclogenesis should be quite easy to anticipate where charts are available at short standard intervals.

The factors involved in the accepted model for cyclogenesis over the Eastern United States can be divided into two classes, according to the height of the atmospheric layers in which the required processes occur. Riehl (5) has described in considerable detail the upper-air (above 500 millibars) patterns which effect the removal of mass. Some mechanism, such as this, is necessary for cyclogenesis.

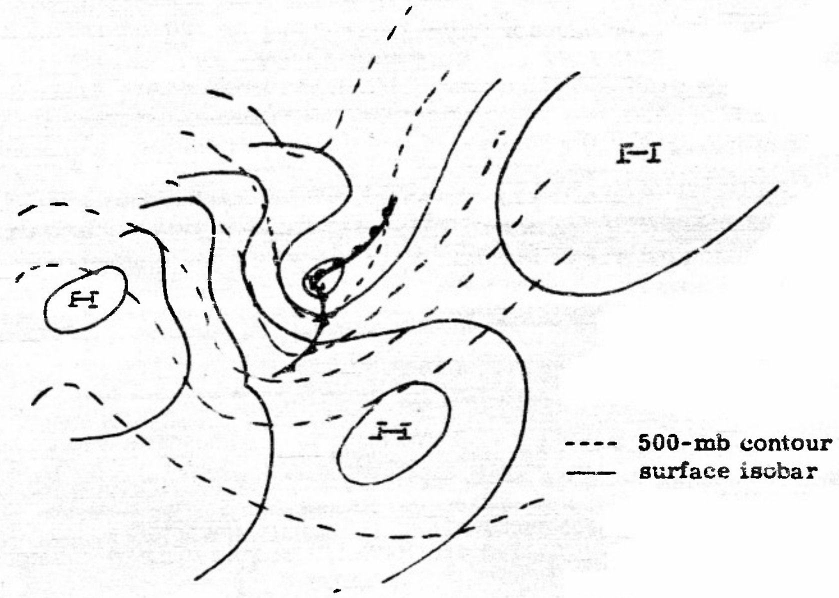
Of equal importance, however, is the existence of a low level thermal pattern, and a wind flow which intensifies the proper gradients of this low-level thermal pattern. George (2) has found that in some cases this low-level baroclinic pattern is a sufficient condition for the prediction of a new storm, or the intensification of an old one.

These two classes of processes, one operating in the upper atmosphere, and the other in the layer near the ground, result in a classical Norwegian-type cyclone, nearly always with an open-wave pattern over it at 500 millibars, but with the upper trough displaced toward the west. This sloping with height is the consequence of the thermal gradient below the 500-mb level (Fig. 1).



In attacking the problem of cyclogenesis over the Mediterranean, a listing of surface lows was prepared in order to isolate a number of cases corresponding to Fig. 1. No cyclones of this type were found. Instead, the appearance of a surface low coincided with the formation of a 500-mb trough, or even closed contour almost directly over it. This dependence of the surface low on the upper pattern leads directly to the consideration that, by correctly predicting the upper contour configuration, surface cyclogenesis can be anticipated in this area.

The typical Mediterranean pattern is illustrated in Fig. 2.



In most cases, this cyclogenesis is quite independent of surface fronts, and in several instances was so analyzed. Storms Numbers 1, 3, 4, 10, and 15 of the sixteen synoptic examples following illustrate the formation of the new low, separate from the surface frontal system.

This indicates further that the low-level indications used by George[1] do not apply in this area, and attention should be focused on 500-mb and higher levels.

To test semi-quantitatively this thesis that there is a fference in importance in the two classes of factors affecting cyogenesis over the Mediterranean and over the United States, the ollowing analysis was performed. Twenty cases of cyclogenesis were selected at random over the United States from the same period, January 1950 to April 1951, as the sixteen documented storms over the Mediterranean. The following data was taken from the historical analyses.

The 24-hr local change of pressure at the point of cyclogenesis was compared with the 24-hr change in 500-mb height for the same point and same time. The second-day values were the local changes at the position of the surface low on the second day of the existence of the low. The correlation coefficients obtained are listed below for the correlation of surface 24-hr local pressure change at point of cyclogenesis with the 24-hr local height change at 500 millibars over the same point.

	1st Day	2nd Day	Two-Day Sum
Mediterranean	.50	.50	.67
United States	.09	.52	.35

This illustrates the inability of the low-level advection over the Mediterranean to compensate for changes in mass distribution occurring further aloft.

As a further test of these differences, a study was made for the group of United States cyclones compared with the Mediterranean cyclones of the distance between the cyclogenesis and the associated upper trough. Results of the study are summarized below.

	Mediterranean	United States
1st Day	-0.2° Long.	10° Long.
2nd Day	1.6° Long.	8° Long.

The difference is highly significant and is related to the relative strength of the low-level thermal field. The strongly baroclinic United States atmosphere shows a large slope (greater distance from surface low to upper trough); while the weaker low tropospheric thermal patterns of the Mediterranean show a much nearer vertical storm structure.

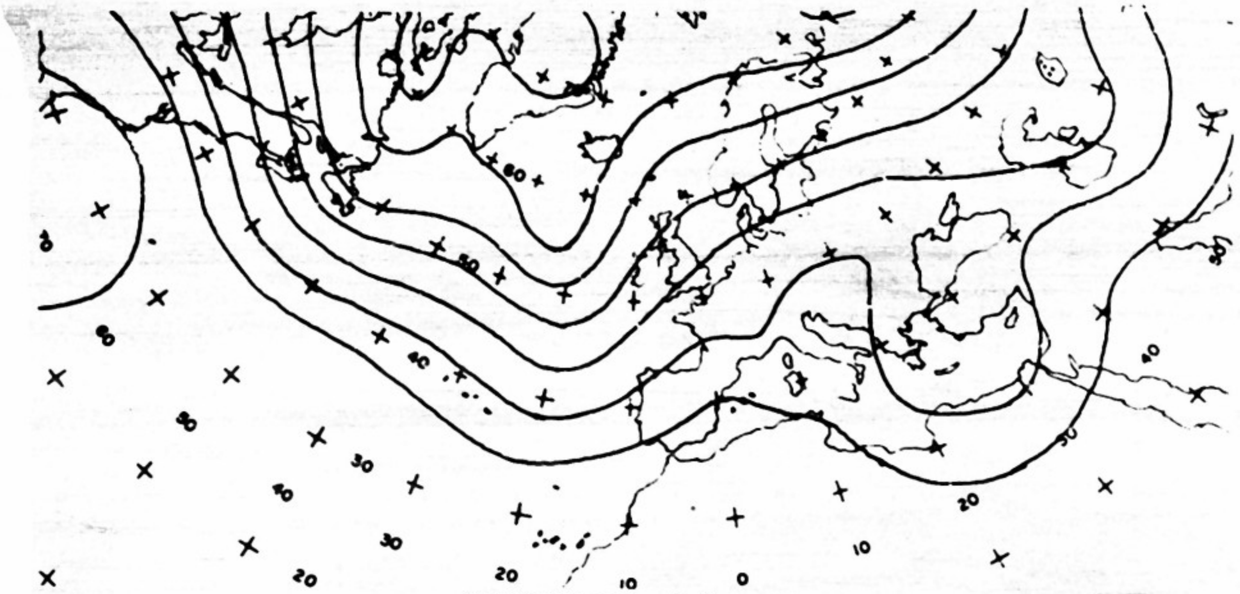
500-MILLIBAR PATTERNS

The charts for the Eastern Atlantic - Western European area may be classified as one of four patterns according to the broad-scale flow. These patterns are southwesterly, northwesterly, blocking and westerly. The frequency of cyclogenesis over the Mediterranean is closely related to the pattern of 500-mb flow. Each of these patterns is illustrated and the frequency and kind of storminess associated with each type is discussed.

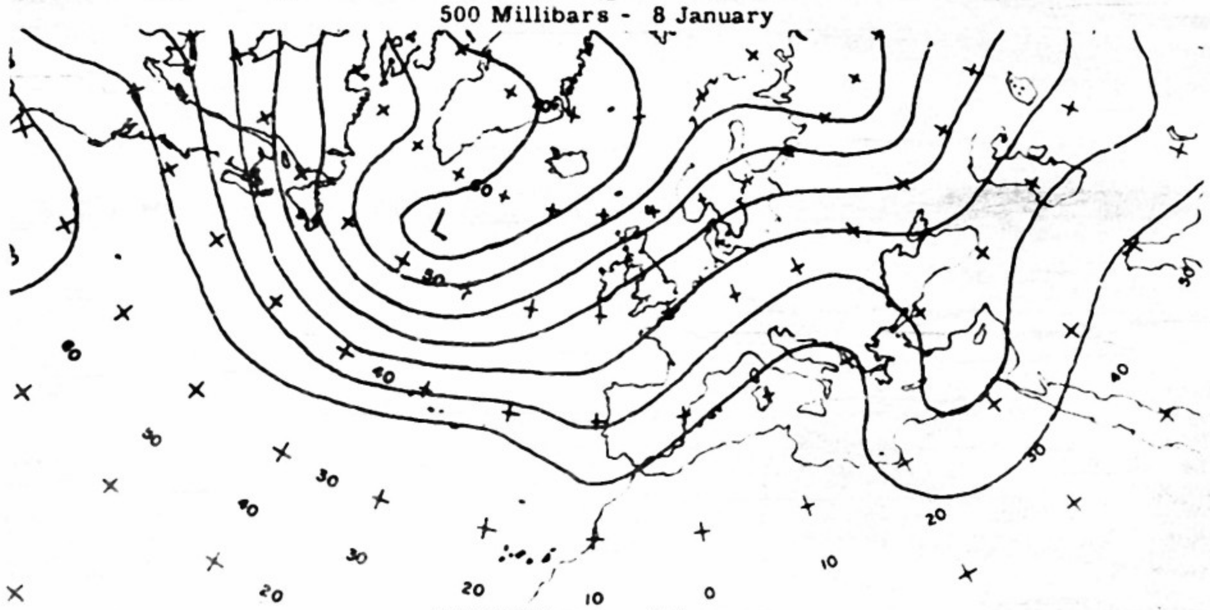
1. SOUTHWESTERLY

Plates I through VI contain a typical synoptic situation accompanying southwesterly flow. As long as this pattern persists, cyclogenesis will not occur in the Mediterranean. Trailing cold fronts in this area may lead the surface chart forecaster to anticipate cyclogenesis, but it will not occur.

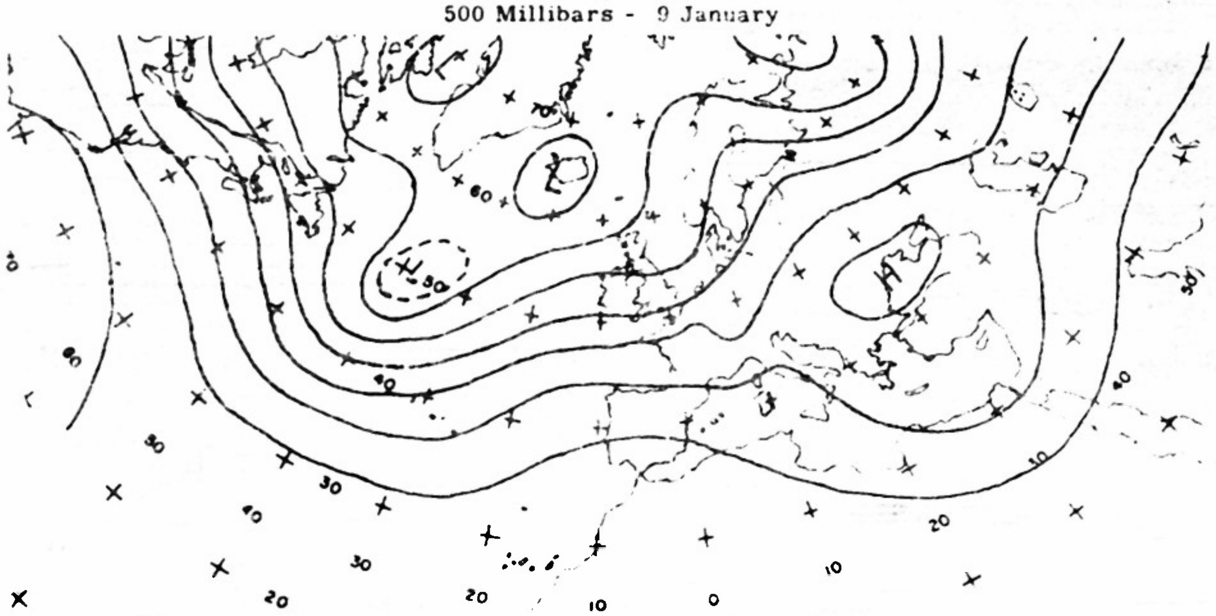
SOUTHWESTERLY PATTERN
Plates I through VI



500 Millibars - 8 January



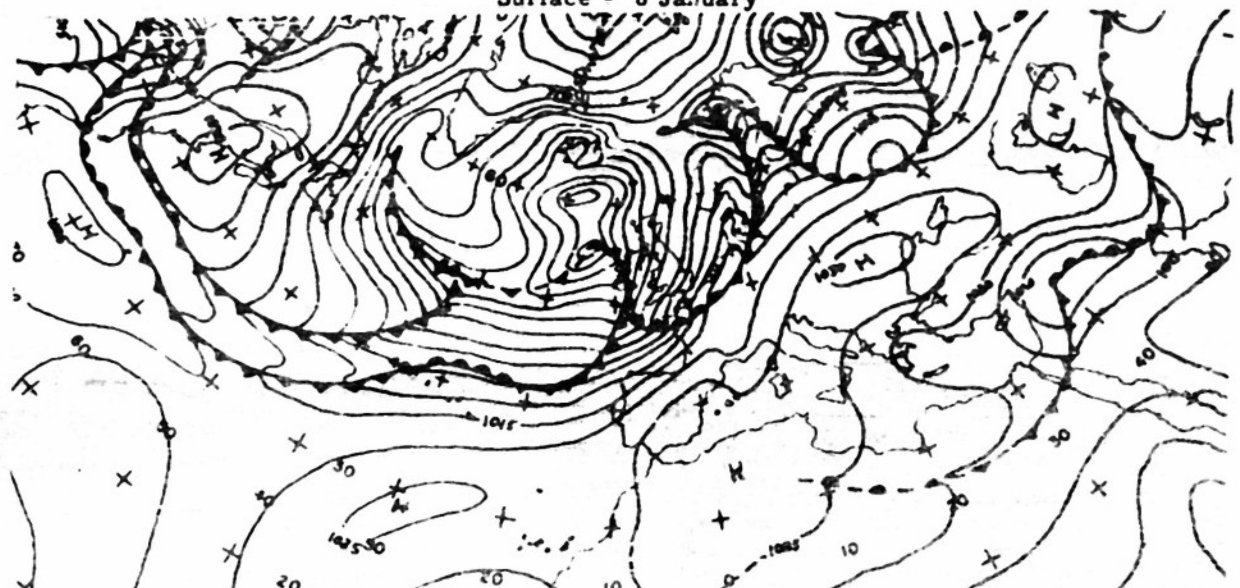
500 Millibars - 9 January



500 Millibars - 10 January

SOUTHWESTERLY PATTERN
Plates I through VI

Surface - 8 January



Surface - 9 January

Surface - 10 January

II. NORTHWESTERLY

Plates VII through XII illustrate a northwesterly pattern. This pattern requires a long-wave ridge in the Eastern Atlantic, and produces repeated cyclogenesis in the Mediterranean. Each short-wave trough, velocity maximum, or, sharpening of the ridge, will be followed by an intensification of the 500-mb low and a deepening at the surface. The surface low will be directly under the upper low and will reflect its changes in intensity and position. December 1950 was a month when northwesterly flow persisted for almost the entire month. The illustration chosen is a period from that month.

It is important to correctly identify this persistent northwesterly pattern. The long-wave trough has an inflection point on its western side every day, and the persistent storminess that accompanies this flow is generally similar to the storms following a westerly pattern. However, the method of the following chapter should not be used after a northwesterly flow is established. Its use is restricted to the initial development following westerly flow. This type of pattern is also illustrated in a recent publication by Elliott and Kerr (3).[1]

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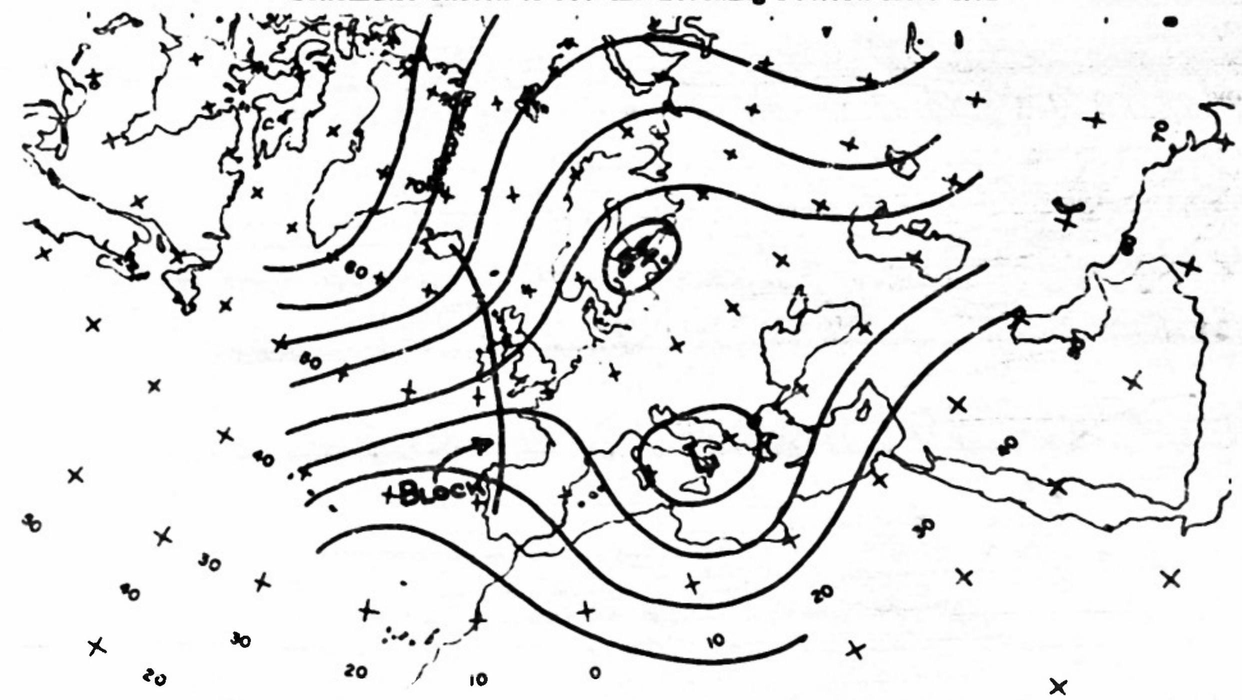
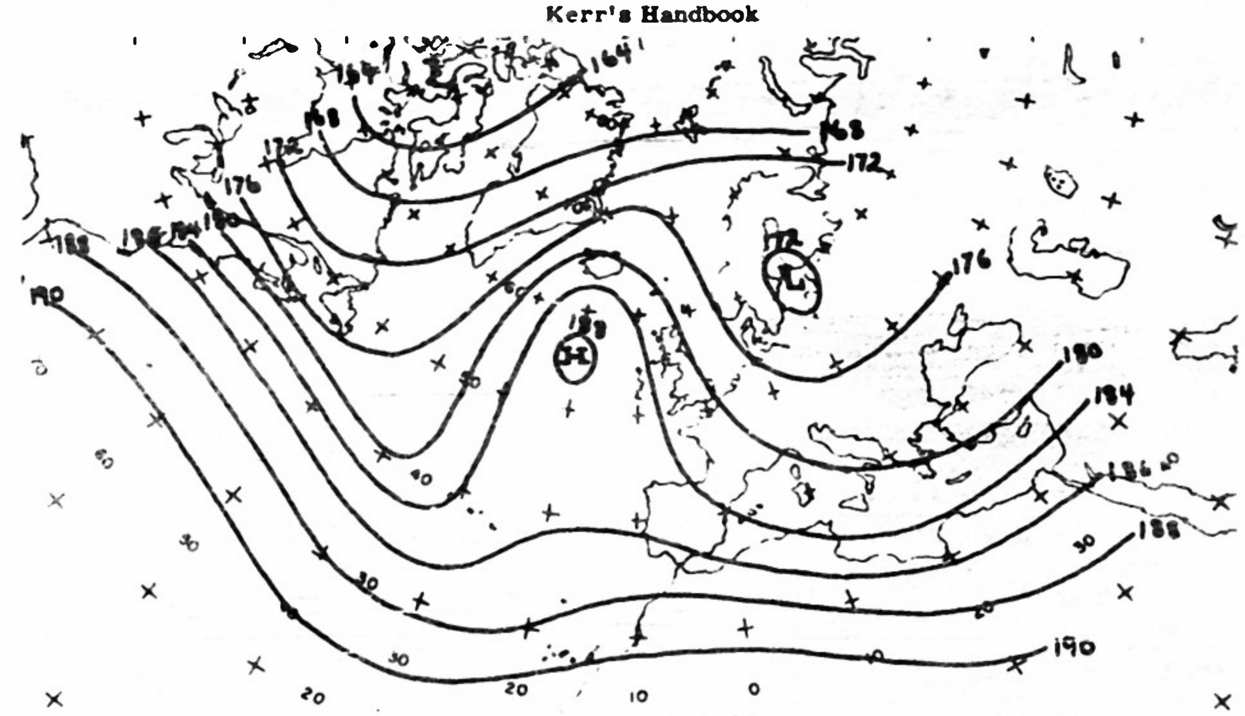
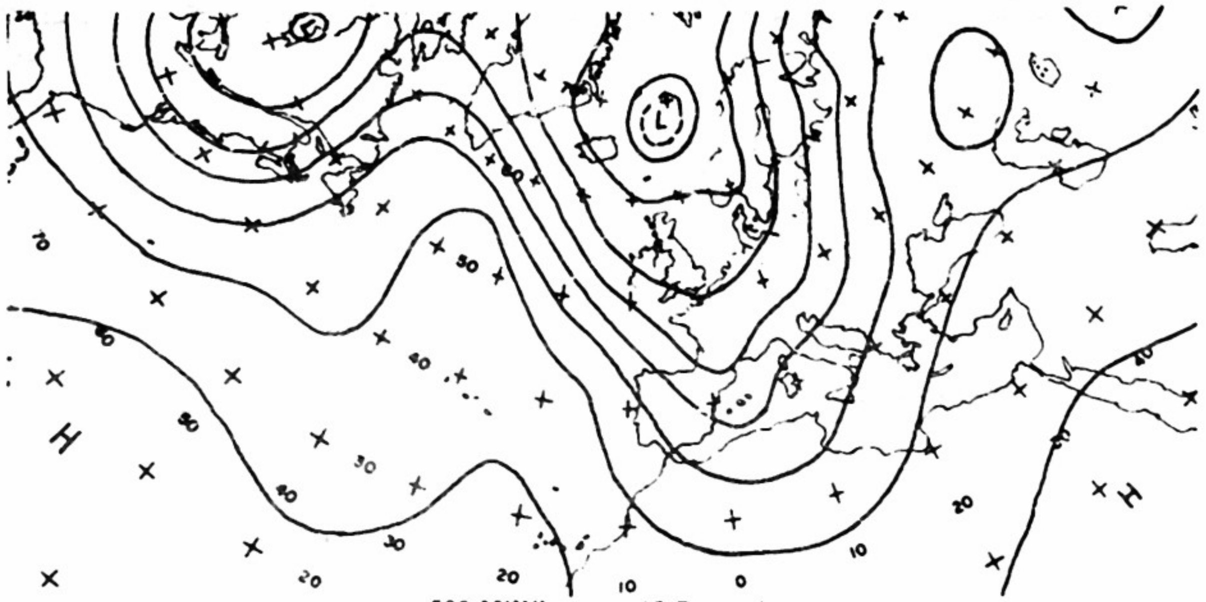
1. The northwesterly type discussed here is the same as the blocking type of Elliott and Kerr, illustrated in Block 1 through 6, pp. 47-57 in their handbook. The 500-mb pattern shown on the next page is taken from Block 2, p. 49. A schematic sketch of the Rex type blocking pattern is also included to show the difference. This paper follows Rex (4) in using the split current definition of blocking.

Schematic Sketch of 500-mb Blocking Pattern after Rex

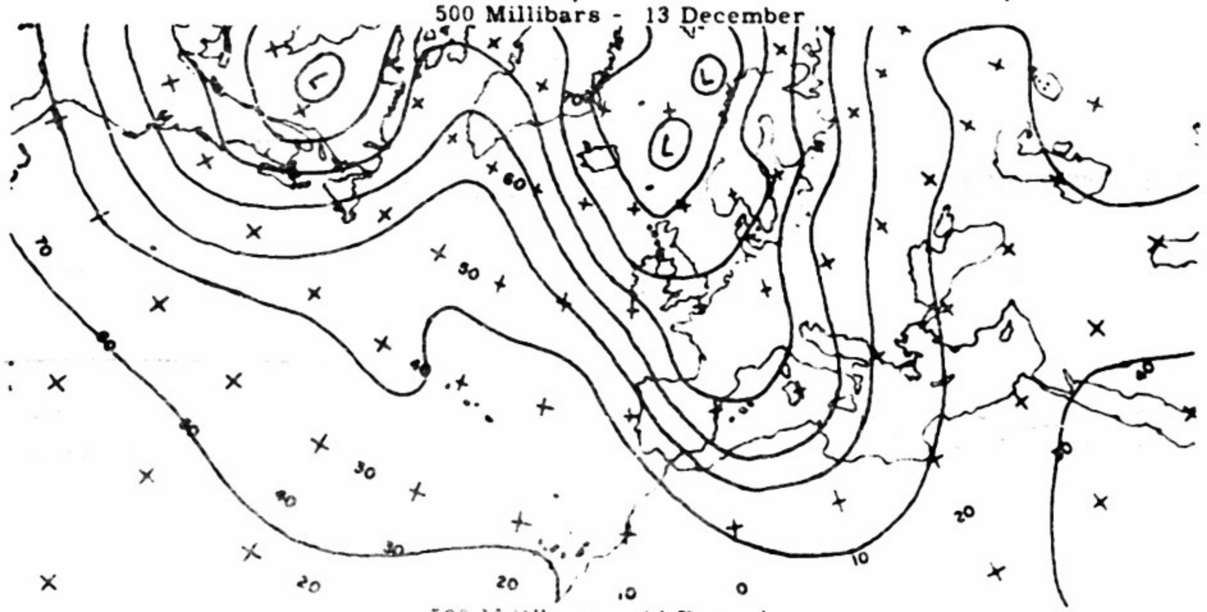


Copy of 500-mb Pattern Taken from Block 2, p. 49 of Elliott and Kerr's Handbook

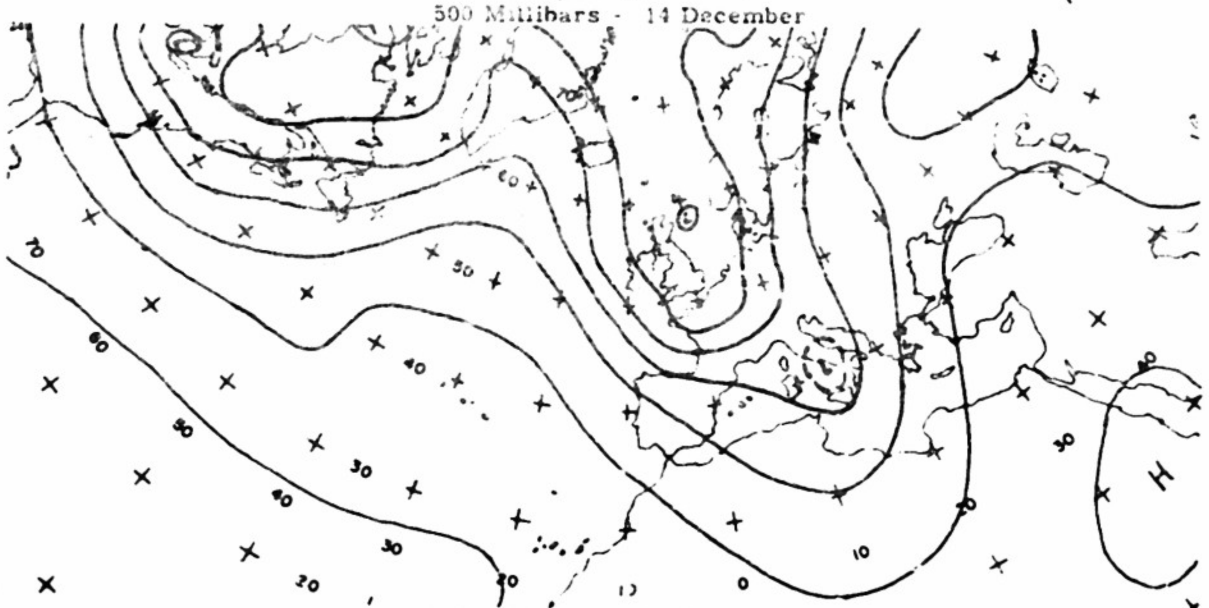




500 Millibars - 13 December



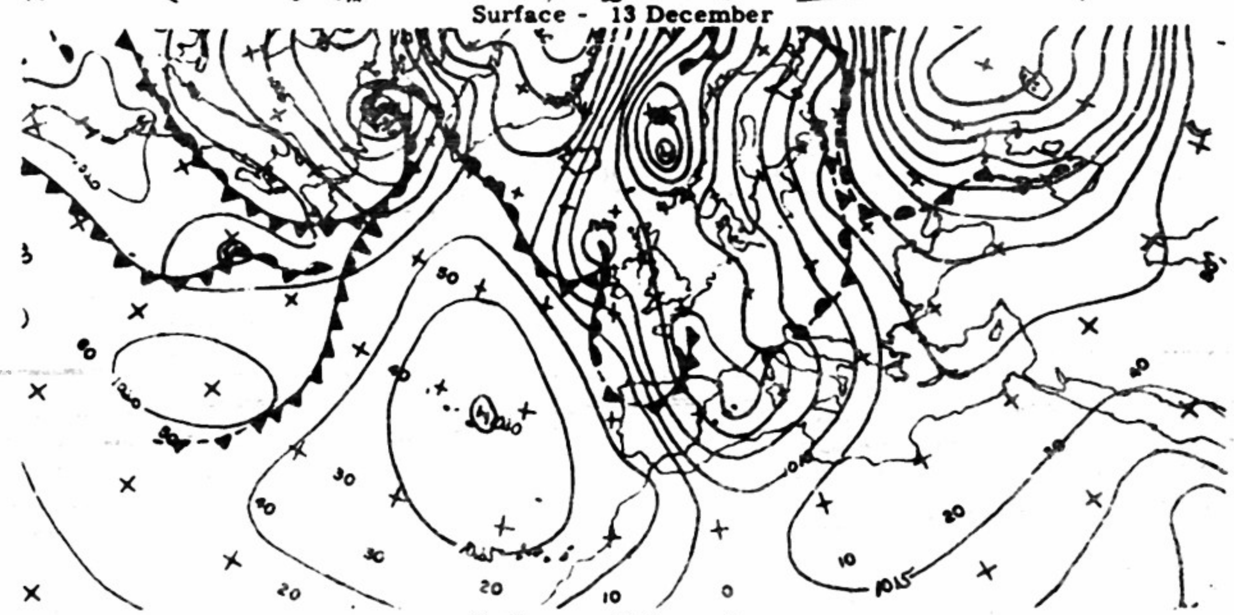
500 Millibars - 14 December



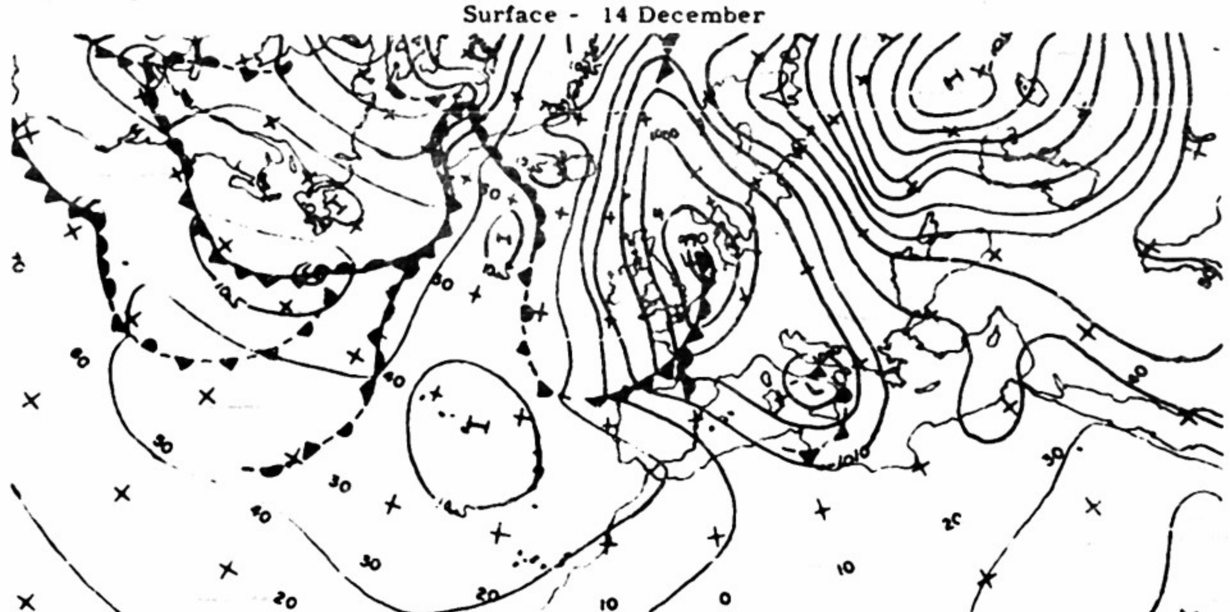
500 Millibars - 15 December

NORTHWESTERLY PATTERN
Plates VII through XII

Surface - 13 December



Surface - 14 December



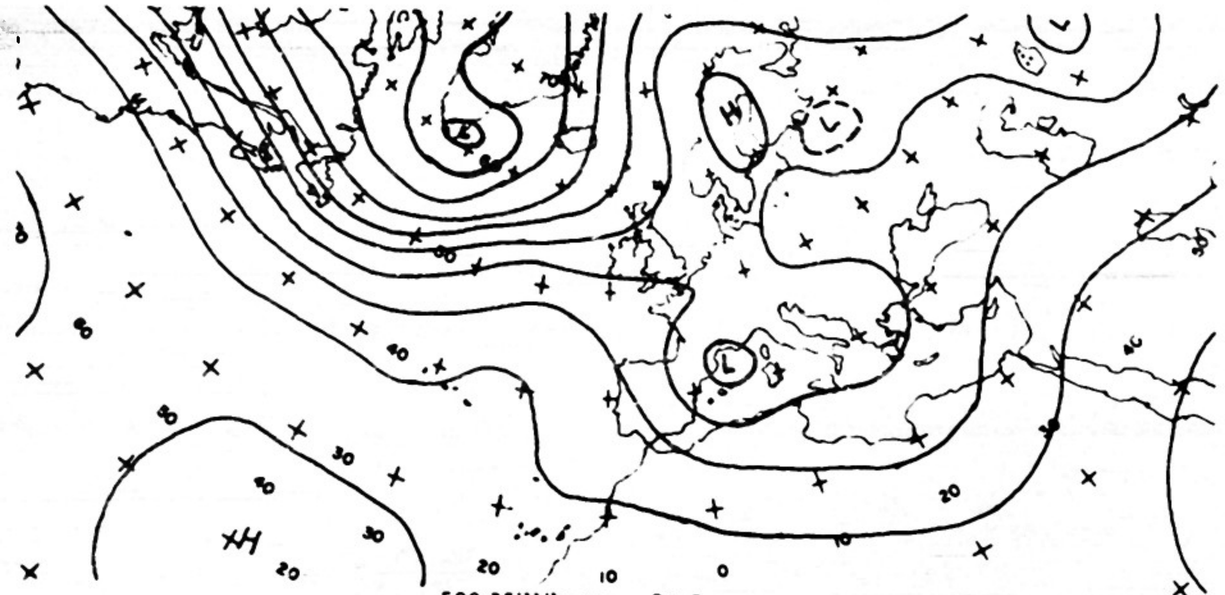
Surface - 15 December

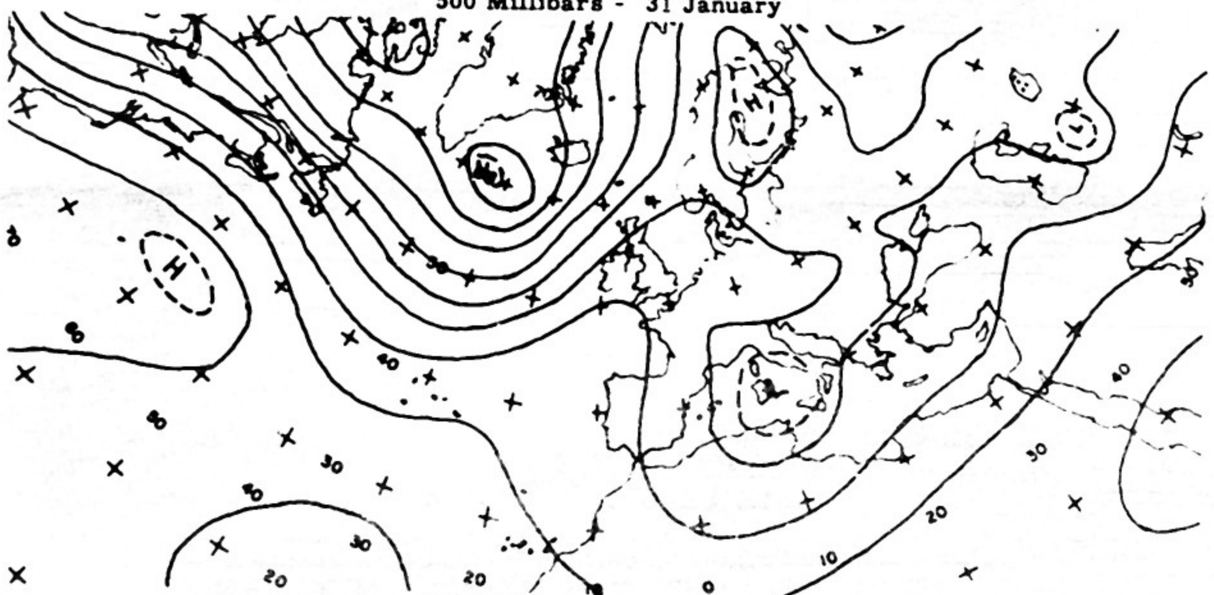
III. BLOCKING

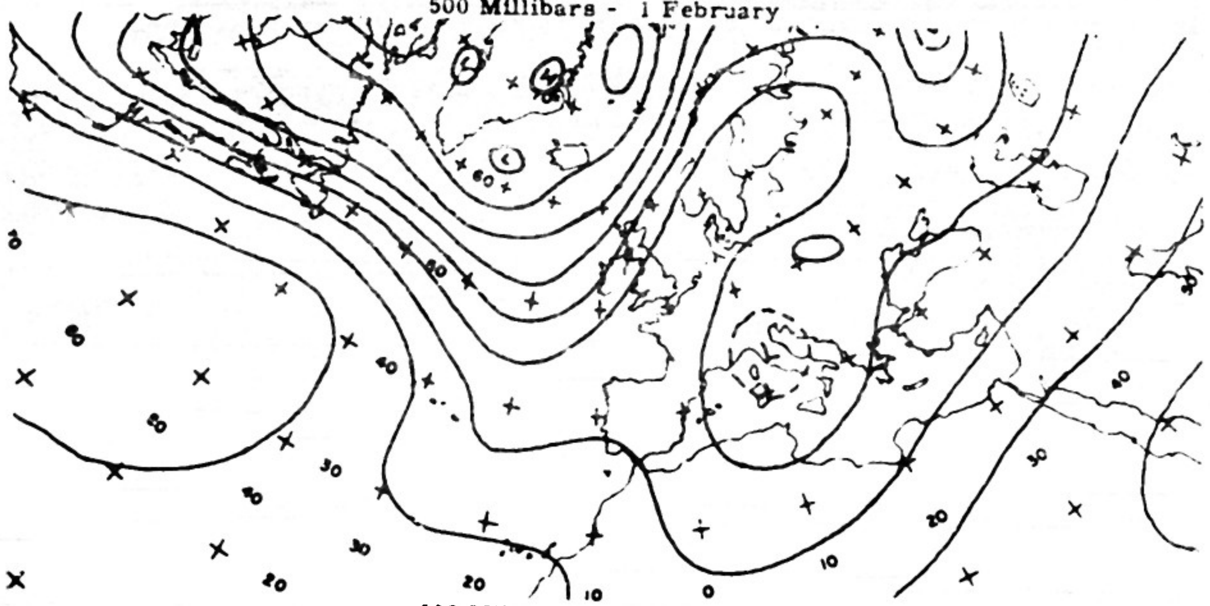
Plates XIII through XVIII illustrate the blocking pattern. Rex (4) has shown that this pattern is very common over Western Europe. A surface low is often present under the low aloft, forming the southern part of the block. This low moves with the upper low also, and reflects its changes in intensity. It may be stationary for sometime under a persistent stable block. As might be anticipated, any attempts to explain these surface lows from frontal patterns are likely to be unsuccessful. In the illustration, the attempts to keep surface fronts in the lows show the difficulty of standard surface-analysis methods in dealing with events largely due to conditions in the upper air.

As shown in the illustration, a block over Western Europe is in effect a northwesterly pattern for an area downstream, and thus repeated storminess is to be expected in the longitude of the Caspian Sea.

BLOCKING PATTERN
Plates XIII through XVIII


500 Millibars - 31 January

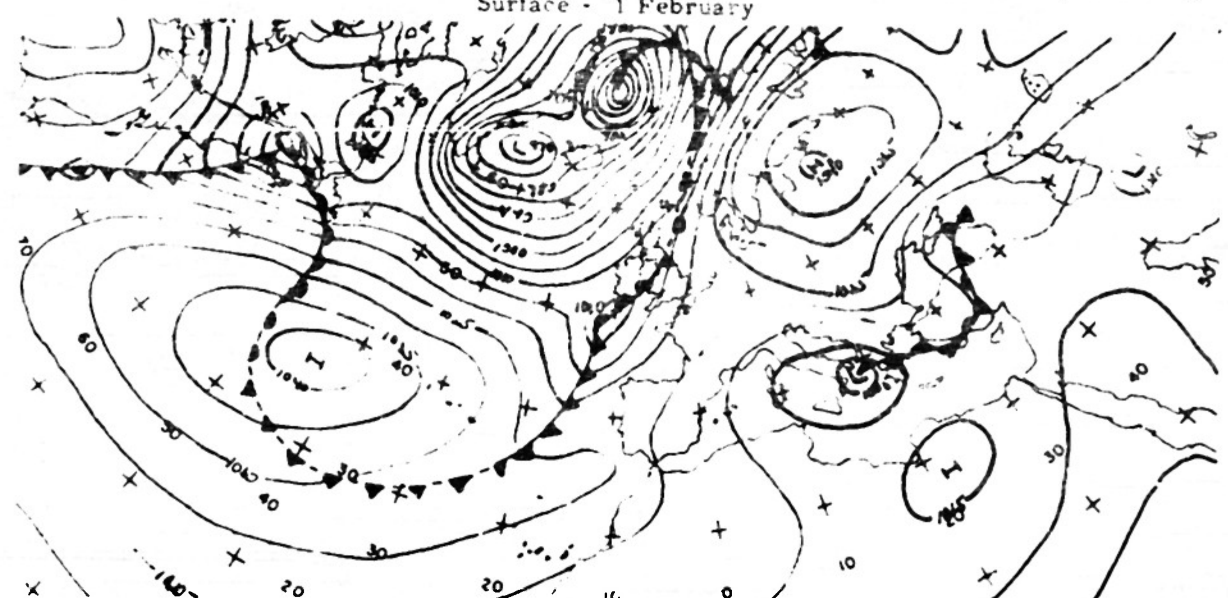

500 Millibars - 1 February


500 Millibars - 2 February

BLOCKING PATTERN
Plates XIII through XVIII


Surface - 31 January


Surface - 1 February


Surface - 2 February

IV. WESTERLY

With a zonal flow pattern, cyclogenesis does not occur over Southern Europe and Mediterranean areas. However, it is following this pattern that some of the most significant storms form in those areas. The frequency of these phenomena may be judged from the 51 cases listed in the chapter on data from 5 winters. It is treated fully in the following section.

MODEL OF CYCLOGENESIS FOLLOWING A WESTERLY PATTERN

As was explained in the preceding section, a strong zonal pattern is not accompanied by storminess over Southern Europe. The transition from westerly to northwesterly flow at 500 millibars results in cyclogenesis in this area.

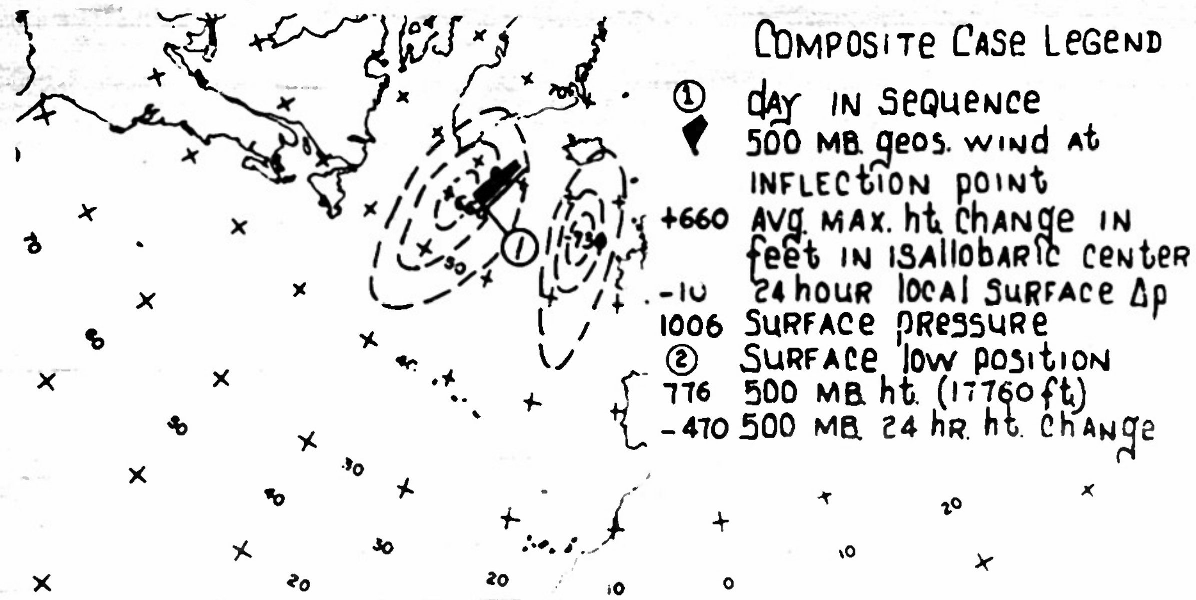
This development was studied using the Historical Maps. Fifty-one cases of this type cyclogenesis are recorded in the following section. It was then noted that the time interval between the surface and 500-mb chart was changed between 1949 and 1950. The 500-mb charts prior to 1950 were for 0300Z.

Sixteen cases since January 1, 1950 were then tabulated and studied in detail. The original predictor was the appearance of a northwesterly current where the flow had been westerly before. Cyclogenesis follows the establishment of such a current in many cases. The sequence of events is apparently as follows:

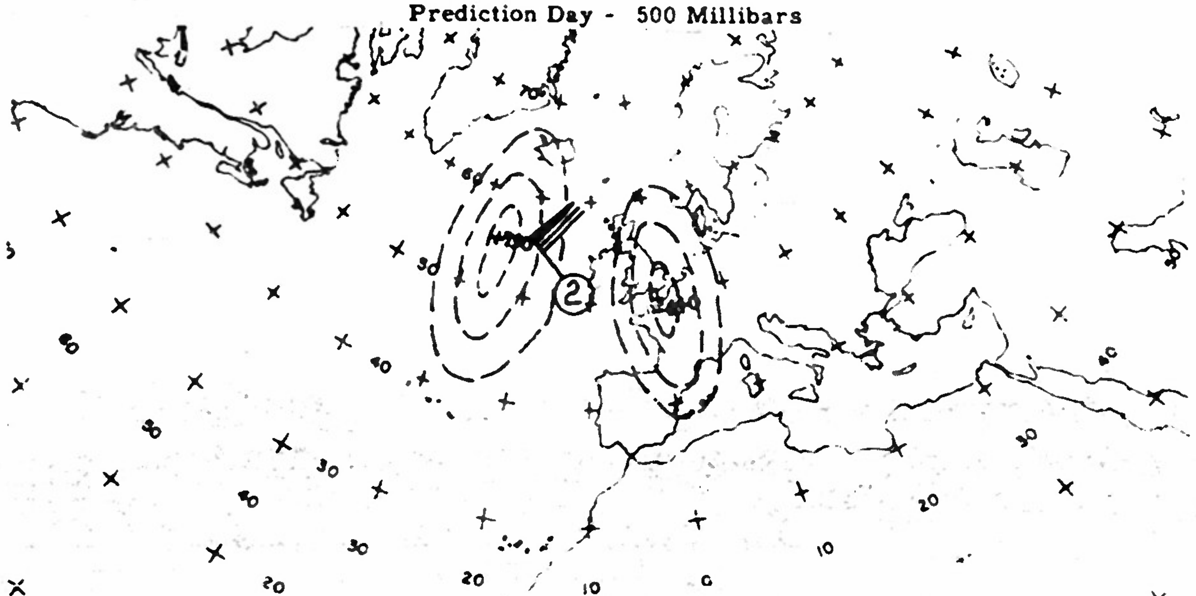
1. At 500 millibars, a northwesterly current is established in the Atlantic following a westerly pattern.
2. This current, following approximately a Constant Absolute Vorticity Trajectory, sets up a trough extending southward over Southern Europe.
3. Surface cyclogenesis takes place directly under this moving trough.

The local changes of pressure and height at the point of cyclogenesis and at the location of the low on the second day of its existence were then studied. The consistency of these height and pressure changes suggested that 24-hr centers at 500 millibars might help in forecasting this cyclogenesis. The historical height-change charts being prepared at Project AROWA were examined and it was found that the inflection point of the northwesterly current is always associated with a pair of moving height-change centers existing on Day One. This coincidence is amply illustrated in the synoptic examples included.

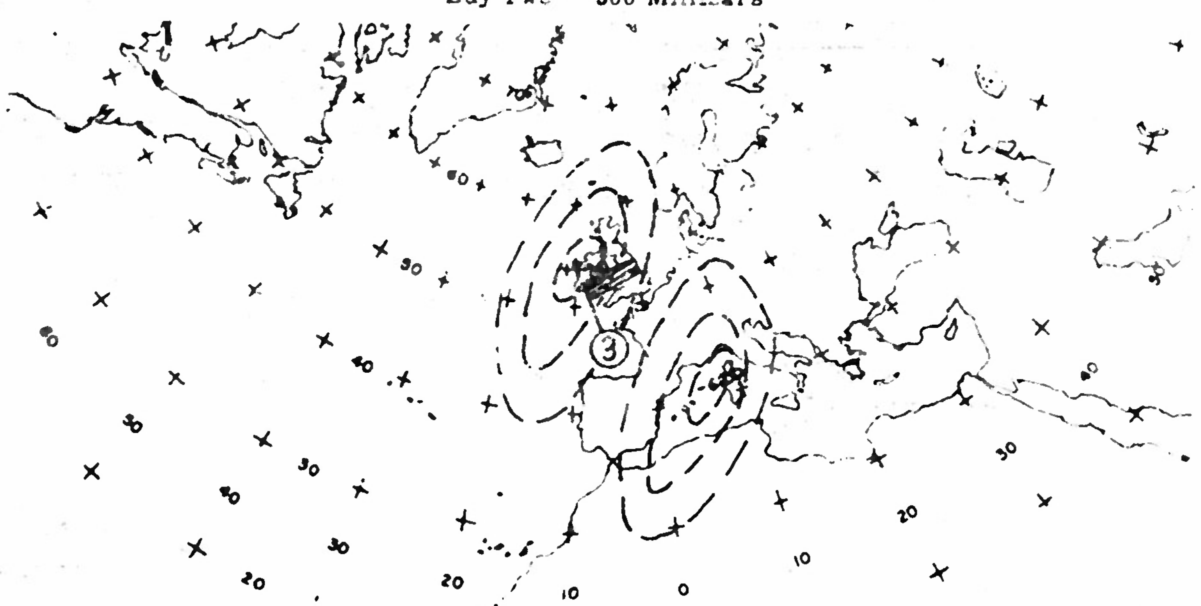
All data from the sixteen recent cases was tabulated and a composite case was prepared. This composite case is illustrated below.



Prediction Day - 500 Millibars

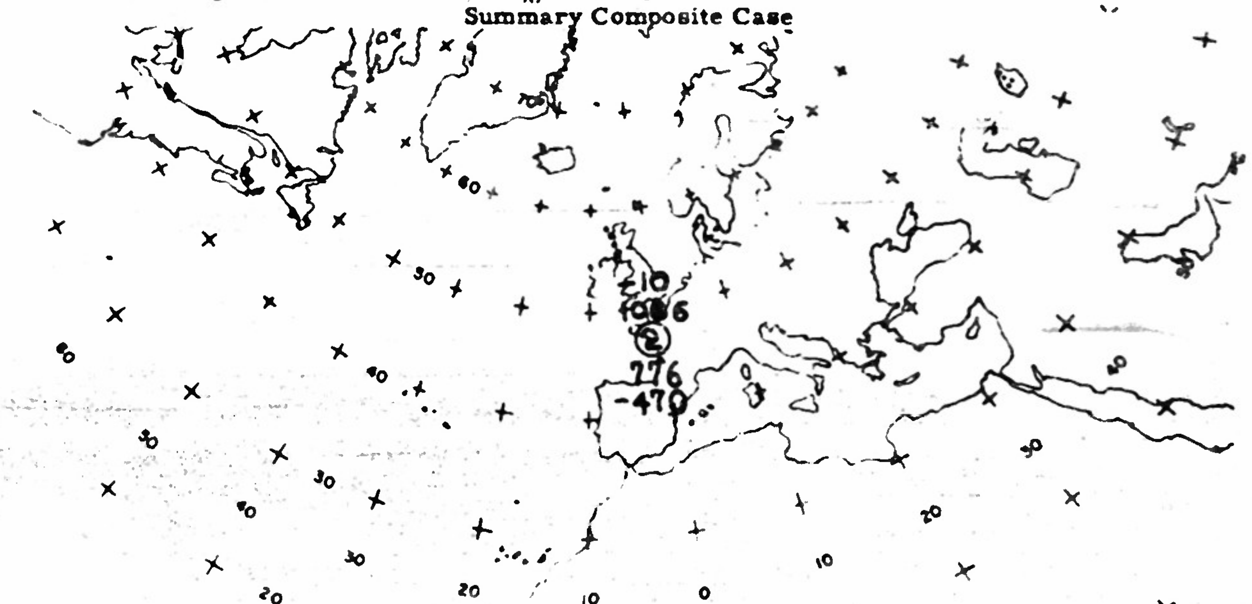


Day Two - 500 Millibars

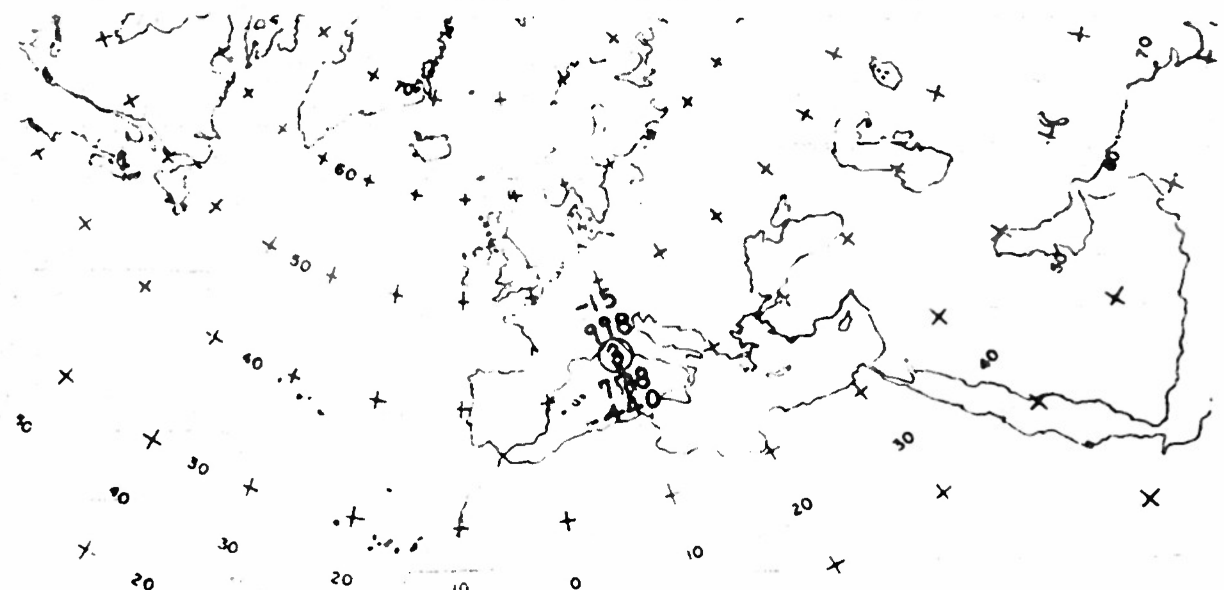


Day Three - 500 Millibars

Summary Composite Case



Day Two - Surface



Day Three - Surface

DATA FROM COMPOSITE CASE

	INFLECTION				CYCLOGENESIS					
#	Lat.	Long.	Spd.	Orientation	Lat.	Long.	Pres.	Pres. Change	Hgt.	Hgt. Change
1	54°	27°W	71	303°						
2	51°	13°W	69	320°	47°	01°W	1006	-10	776	-470'
3	46°	05°W	68	343°	43°	09°E	998	-15	778	-440'

CASE COMPOSITE HEIGHT CHANGES

Day	Inflection		Height Rise		Center of Rise	Fall		Fall Center
	Lat.	Long.	Lat.	Long.		Lat.	Long.	
1st Day	54°	27°W	56°	39°W	+660'	56°	19°W	-730'
2nd Day	51°	13°W	55°	24°W	+790'	49°	01°E	-640'
3rd Day	46°	05°W	53°	09°W	+740'	41°	07°E	-620'
4th Day	42°	01°E	50°	06°W	+460'	34°	08°E	-600'

The similarity of the composite case to many of the individual storms lends meaning to this average. This also strongly suggests that a forecast of cyclogenesis can be made 48 hours in advance. This prediction is made by selecting the point for the anticipated cyclogenesis, by moving an average number of degrees south and east of the inflection point with suitable tendency at 500 millibars.

Since the location of the inflection may be subjective, another scheme for a reference point was devised. This point is determined as follows. Draw a line between the height-rise and height-fall centers at Day One, and mark the reference point at the intersection of the 100-foot rise isallobar and this line.

Then on Day Two, another check can be made and a new prediction of the storm made for Day Three.

The $\Delta\phi$ and $\Delta\lambda$ between the reference points and the cyclogenesis are summarized in the following table. These data show that the inflection point of the current or the reference point at the intersection of the line through the tendency centers and the plus 100-ft isallobar may be used with equal accuracy in determining the point of subsequent cyclogenesis.

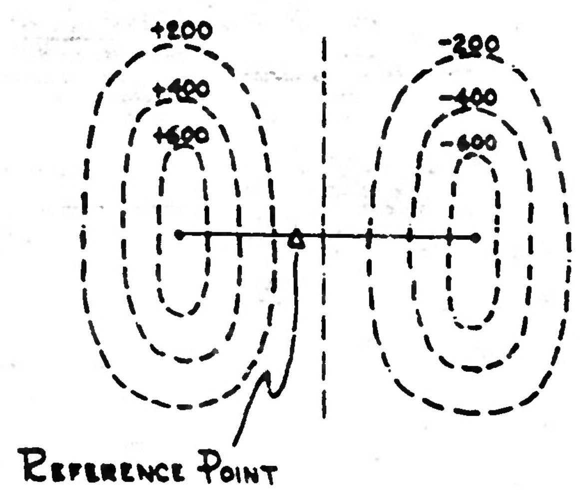
COMPARATIVE DATA FOR REFERENCE POINTS

		Lat.	Long.	Day	Degrees
1st Day	Inflection	54°	27°W	1	$\Delta\phi$ = 11S
3rd Day	Cyclogenesis	43°	09°E	3	$\Delta\lambda$ = 36E
2nd Day	Inflection	51°	13°W	2	$\Delta\phi$ = 8S
3rd Day	Cyclogenesis	43°	09°E	3	$\Delta\lambda$ = 22E

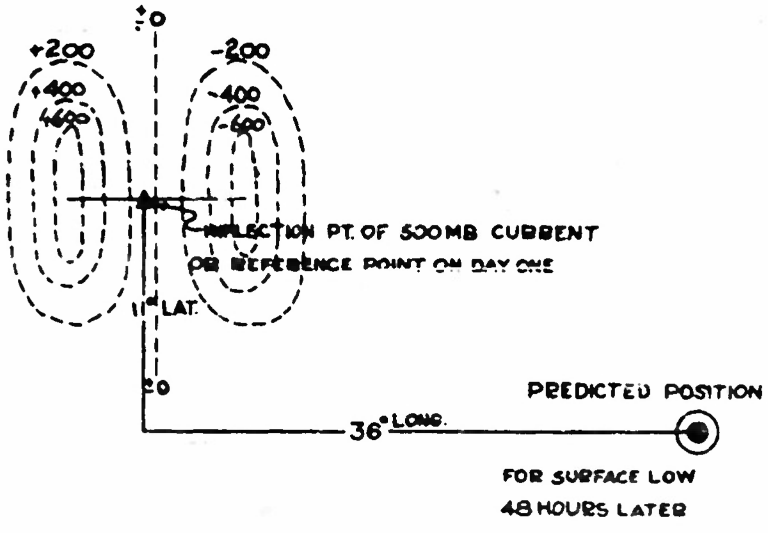
1st Day	Reference	55°	27°W	1	$\Delta\phi$ = 12S
3rd Day	Cyclogenesis	43°	09°E	3	$\Delta\lambda$ = 36E
2nd Day	Reference	52°	09°W	2	$\Delta\phi$ = 9S
3rd Day	Cyclogenesis	43°	09°E	3	$\Delta\lambda$ = 18E

In applying this average displacement, some variation should be allowed for the well-known preference for surface lows off cyclonically curved coastlines. Thus a prediction point over Northern Italy should be moved slightly East or West to either of the favored spots over water East and West of the Italian Peninsula.

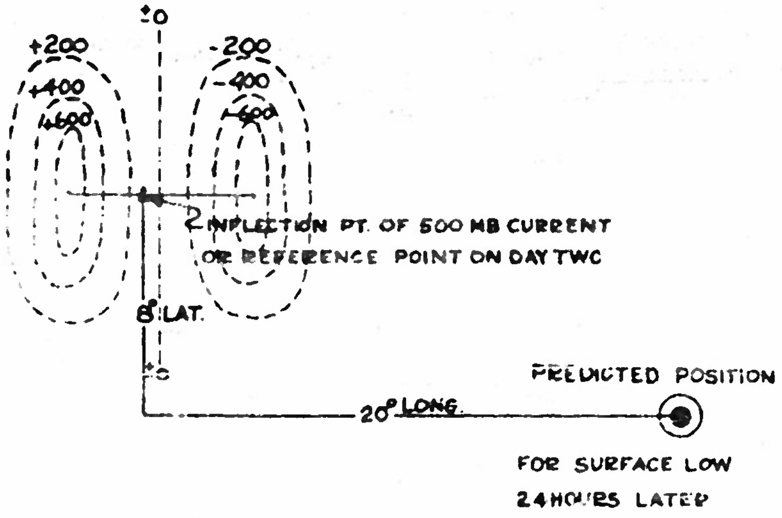
ILLUSTRATION



48 Hour Prediction



24 Hour Prediction



NOTE: These Illustrations Are Not To Scale

ERROR ANALYSIS

Case	48-hr Error in λ	48-hr Error in φ	24-hr Error in λ	24-hr Error in φ
1	7°E	0	1°E	1°S
2	12°W	7°N	4°W	4°N
3	3°E	7°N	3°E	9°N
4	10°W	4°N	5°W	6°N
5	5°E	4°N	2°E	1°N
6	13°W	1°S	16°W	0
7	15°E	2°N	3°E	2°N
8	5°W	4°N	4°W	5°N
9	1°W	10°S	2°W	7°S
10	9°E	6°N	6°E	2°N
11	0	6°S	6°W	3°S
12	5°W	2°N	1°W	0
13	1°E	5°S	5°W	2°S
14	3°W	7°S	3°E	6°S
15	4°W	4°S	7°W	8°S
16	4°E	2°N	3°W	1°N

Average Error

48-hr Prediction Error in λ	48-hr Prediction Error in φ	24-hr Prediction Error in λ	24-hr Prediction Error in φ
6°	4°	5°	3°

These errors were measured from the actual position of the new low on Day Three to the predicted position. The chief cause of these variations is the obvious fact that the storms are in somewhat different stages of development at 1500Z on prediction day. This fact makes some variation in position inherent in schemes developed from charts at 24-hr time intervals. Of course some lows moved faster than others, and there is some connection between the speed of advance of the tendency centers and the distance to the cyclogenesis.

In this listing of forecast errors, as well as throughout this entire paper, the variation of the size of a degree of longitude with latitude has been neglected. With 24-hr continuity only, and while dealing with a phenomenon, such as cyclogenesis, it is considered that such refinements are unnecessary. The emphasis here belongs on the prediction that a considerable cyclone will develop in an area that has not been stormy in the past several days. If this large-scale development has been anticipated, the exact location will be a matter for shorter range forecasts. In this connection, it is noted that the error of the 24-hr prediction is less than that of the 48-hr forecast.

In applying the method, the recognition of the 500-mb flow pattern and the model of development are essential. It is suggested that a forecaster being assigned to the Mediterranean area familiarize himself with as many as possible of the 51 storms listed in the following chapter. This can be done by checking through the Historical Series for the dates listed, and observing synoptic events at the surface and 500 millibars. If a set of 500-mb, 24-hr height-change charts is available, they should be studied also.

The question may arise of the appearance of the 500-mb contour chart and height-change chart on the day before "prediction day". A few qualitative observations may be made here. The appearance of the moving short-wave ridge over the Atlantic came about in several different ways for the storms studied. Some of the ridges moved out off the continent and then slowly intensified with the height-fall center appearing on prediction day to give the characteristic tendency pair.

A more frequent type of development was noted. A storm deepens off North America, with an increase of southerly flow at

500 millibars associated with it. This event is followed in one to two days by a rise in 500-mb height with a moving ridge which, as it procedes eastward, provides the prediction-day pattern as illustrated in the composite case. Again, however, the important thing is the recognition of the prediction-day pattern and the subsequent developments following the model.

DATA AND SYNOPTIC EXAMPLES

The original tabulation of cyclogenesis following a westerly pattern is reproduced below. The left-hand column includes data from the inflection point of the 500-mb pattern. The right-hand column is made up of data from the surface cyclone. The data in this table was not altered when the more comprehensive study was made on the last 16 cyclones.

Many of the examples closely resemble the composite case in all respects. Others show individual peculiarities in one or two respects. For example, several cases show a speed maximum in a westerly current instead of an inflection, but with height changes according to model (example, Cases 8 and 13). In others, the isallobaric changes may be of lesser magnitude than average. Fortunately the cyclogenesis proceeds according to model in these cases.

LEGEND FOR DATA AND EXAMPLES

◀	Inflection point of 500-mb current. The original selection of these inflection points was not altered after the 500-mb height-change pattern was added, making available the other reference point.
●	Location of surface low at map time. On Day Two, this point is located under the 500-mb trough.
◉	Predicted position for surface low on Day Three. This 48-hr prediction was made by locating a point 11° Lat. south and 36° Long. east of inflection point at 500 millibars on Day One.
----	200-ft, 24-hr, height-change line.
+550	Estimated maximum 24-hr, height-change in isallobaric center at 500 millibars.
815	500-mb height (18,150 feet)

Explanation of Models in Case Summaries

1	Location of 500-mb inflection point on Day One. Geostrophic wind at that point indicated.
-3	Local change of surface pressure for period Day One to Day Two at this point.
1018	Surface pressure at this point on Day Two.
2	Location of surface low on Day Two of sequence.
815	500-mb height at this point on Day Two. (18,150 FT.)
-250	Local change of 500-mb height for period Day One to Day Two at this point.

N = 51

		INFLECTION			CYCLOGENESIS			
Date	Lat. (Degrees)	Long.	Orientation (Degrees)	Speed (Geo. Kts.)	Lat. (Degrees)	Long.	Surf. Pres. (mb)	500-mb Height (feet)
4/1/51	54	18W	310	55				
4/2/51	50	08W	330	40	43	02E	1018	815
4/3/51					43	11E	1013	800
3/22/51	62	39W	350	35				
3/23/51	56	17W	310	60	49	10W	1007	815
3/24/51	54	06W	320	95	44	07E	998	790
3/25/51	46	01E	350	90	42	15E	993	765
3/26/51	62	26W	320	30				
3/27/51	61	10W	350	45	48	00	1005	769
3/28/51					44	07E	1002	810
2/4/51	50	38W	300	130				
2/5/51	49	17W	310	80	43	02W	987	702
2/6/51	48	14W	315	95	35	08E	997	802
2/7/51					41	14E	993	775
12/31/50	52	21W	305	90				
1/1/51	50	23W	335	65	45	13W	1002	750
1/2/51	48	13W	330	55	41	01W	993	759
1/3/51	37	00	335	100	41	08E	993	755
1/11/51	48	31W	295	80				
1/12/51	46	18W	315	70	45	06E	1003	772
1/13/51	44	00	310	40	38	18E	994	777
1/14/51	54	04W	290	65				
1/15/51	51	00	320	70	47	05E	1007	798
1/16/51	44	06E	005	75	41	17E	997	759
1/17/51	55	23W	270	70				
1/18/51	53	06W	310	70	46	09E	1012	815
1/19/51	49	05E	335	65	40	18E	995	788
1/20/51					41	30E	987	787
1/21/51	49	45W	295	90				
1/22/51	49	30W	320	60	47	20W	1018	778
1/23/51	46	20W	355	75	48	08W	1000	773
1/24/51					42	04W	1000	757
11/28/50	60	21W	335	35				
11/29/50	53	08W	330	70	47	02E	1013	803
11/30/50	44	06E	355	85	43	06E	1002	806
10/17/50	56	01W	290	100				
10/18/50	56	09E	315	90	54	25E	999	767
10/19/50	52	17E	005	55	51	35E	990	760
4/1/50	57	30W	290	100				
4/2/50	52	10W	335	65	48	02E	1000	760
4/3/50	44	01W	355	70	44	11E	987	740
4/14/50					42	17E	986	758
4/4/50	43	59W	280	80				
4/5/50	48	47W	300	100	42	32W	1013	820
4/6/50	40	35W	350	55	42	22W	990	780

		INFLECTION			CYCLOGENESIS			
Date	Lat. (Degrees)	Long.	Orientation (Degrees)	Speed (Geo. Kts.)	Lat. (Degrees)	Long.	Surf. Pres. (mb)	500-mb Height (feet)
2/5/50	47	24W	285	90				
2/6/50	45	02W	310	70	43	07E	1008	777
2/7/50					43	15E	1008	790
2/12/50	51	28W	325	40				
2/13/50	44	15W	315	70	49	05W	988	717
2/14/50	40	04W	335	60	44	12E	1003	775
1/15/50	58	22W	310	40				
1/16/50	54	13W	340	80	53	02E	1011	757
1/17/50	46	03W	005	60	45	10E	1004	738
12/30/49					41	04W	1000	813
12/29/49	42	36W	330	65	44	17W	970	777
12/28/49	49	46W	300	55	35	20W	985	831
12/27/49	49	47W	300	65				
12/19/49	48	11E	335	75	39	28E	985	802
12/18/49	51	05E	315	90	43	21E	995	780
12/17/49	53	12W	275	110				
11/19/49	47	23W	305	50	46	00	990	783
11/18/49	48	34W	295	55	42	12W	995	823
11/17/49	48	38W	295	70	42			
11/15/49	48	01W	360	100	42	10E	1000	787
11/14/49	50	04W	345	80	43	12E	1000	809
11/13/49	52	16W	295	55				
11/8/49	41	04E	320	85	44	20E	990	786
11/7/49	48	05W	305	80	44	12E	985	760
11/6/49	50	15W	295	60	49	09W	985	778
11/5/49	52	32W	300	90				
10/27/49	50	03W	360	80	42	09E	1010	869
10/26/49	48	16W	310	70	41	02W	1015	882
9/25/49	45	27W	345	65	44	13W	1005	833
9/24/49	49	31W	320	75				
4/27/49	48	05W	020	50	41	13E	1015	841
4/26/49	50	07W	350	70	43	10E	1000	826
4/25/49	52	14W	315	70	41	07E	1000	839
4/24/49	53	29W	300	65				
4/8/49	52	05W	320	75	45	12E	1005	795
4/7/49	48	14W	310	65				
3/9/49	40	27W	360	80	42	12W	990	758
3/8/49	53	27W	005	70	48	11W	990	777
3/7/49	54	33W	340	55	55	13W	995	778
3/3/49					45	27E	985	742
3/2/49	52	01E	340	90	42	16E	990	748
3/1/49	55	02W	315	90				

	INFLECTION				CYCLOGENESIS			
Date	Lat. (Degrees)	Long. (Degrees)	Orientation (Degrees)	Speed (Geo. Kts.)	Lat. (Degrees)	Long. (Degrees)	Surf. Pres. (mb)	500-mb Height (feet)
2/12/49					39	39E	1000	808
2/11/49	53	09E	350	65	42	34E	995	810
2/10/49	54	02W	310	75	58	12E	990	698
2/3/49	50	08E	060	60	36	18E	1000	765
2/2/49	54	11E	025	70	37	18E	1000	772
2/1/49	55	09E	005	80	38	14E	1010	795
1/23/49	56	28E	355	85	36	27E	1000	813
1/22/49	50	03E	345	80	39	18E	1005	830
1/21/49	58	04E	315	100				
1/3/49					39	07E	1000	817
1/2/49	42	27W	320	100	43	04E	990	769
1/1/49	47	36W	300	85				
9/25/47					40	06E	995	860
9/24/47	50	04W	010	60	44	06E	1005	825
9/23/47	57	11W	325	100				
3/28/47	38	22W	325	100	39	02W	990	813
3/27/47	45	28W	340	60	32	03W	1010	898
3/26/47	50	42W	335	45				
3/25/47	44	03W	340	50	42	12E	1000	812
3/24/47	49	16W	320	45	43	06E	1000	802
3/23/47	52	25W	320	55				
2/19/47	40	03W	315	90	42	16E	985	752
2/18/47	37	12W	340	100	40	10E	995	774
2/17/47	39	26W	305	140	42	02W	995	808
2/5/47	39	06W	320	65	45	18E	985	759
2/4/47	43	13W	310	50	43	08E	980	740
2/3/47	41	29W	295	105	48	07W	970	679
2/2/47	44	40W	285	85				
1/10/47	45	01E	325	60	41	12E	1005	793
1/9/47	45	18W	295	40				
12/29/46	37	00	340	80	38	15E	995	768
12/28/46	40	00	010	90	39	12E	995	760
12/27/46	46	12W	315	70	40	11E	1000	780
12/26/46	53	18W	280	60				
12/14/46	40	01W	355	60	38	11E	1000	803
12/13/46	40	04W	345	50	38	03E	1005	808
12/12/46	46	31W	290	65				
12/5/46	41	00	330	110	40	11E	985	718
12/4/46	45	05W	325	80	41	09E	985	780
12/3/46	47	10W	305	75				

	INFLECTION				CYCLOGENESIS			
Date	Lat. (Degrees)	Long. (Degrees)	Orientation (Degrees)	Speed (Geo. Kts)	Lat. (Degrees)	Long. (Degrees)	Surf. Pres. (mb)	500-mb Height (feet)
11/18/46					47	22E	975	775
11/17/46	37	00	360	80	42	12E	990	808
11/16/46	40	10W	345	70	40	04E	995	797
11/15/46	48	15W	325	55	45	05E	1000	797
11/14/46	48	40W	345	70				
4/30/46					42	13W	985	777
4/29/46	50	25W	350	60	48	08W	985	763
4/28/46	58	45W	295	70				
2/27/46	45	21W	345	50	41	13W	985	769
2/26/46	46	24W	330	65	35	15W	1010	819
2/25/46	46	39W	290	90				
2/26/46	46	24W	330	65	48	05W	1000	781
2/25/46	46	39W	290	90				
2/10/46	45	07E	040	50	47	30E	990	745
2/9/46	54	05W	345	75	41	11E	1000	793
2/8/46	55	03W	285	65				
12/18/45	44	23W	295	80	49	13W	950	671
12/17/45	47	28W	310	80				
12/8/45					39	20E	990	834
12/7/45	45	01E	005	55	39	20E	990	778
12/6/45	49	02E	340	80	40	10E	1005	797
12/5/45	48	01W	300	60				
11/29/45	32	14E	350	60	35	25E	995	800
11/28/45	45	07E	340	60	36	23E	995	802
11/27/45	58	06E	355	55	43	08E	1005	794
11/9/45	55	00	360	60	43	12E	990	870
11/8/45	62	10W	310	80				
11/6/45	41	33W	020	65	38	24W	985	779
11/5/45	49	37W	340	65	39	21W	985	843
11/4/45	49	45W	300	70	41	25W	995	844
10/30/45	42	07W	015	55	38	05E	1000	822
10/29/45	45	16W	340	65	45	04W	990	787
10/28/45	46	25W	335	80				

The sixteen cases occurring since 1 January 1950 were then studied in considerable detail. (The data is summarized in the following table which precedes the illustration of these storms.)

The inflection points on Day One are in the geographic area 40°N Latitude to 65°N Latitude and 50°W Longitude to 0° Longitude. The development in the next two days then produces a surface storm south of 50°N Latitude. This method should be applied only in the area outlined here.

Several sequences of events, shown in the composite case, are also illustrated by almost all of the tabulated storms and should be mentioned here. The wind direction at the inflection point shifts toward the north with time. The intensity of the cyclogenesis is not simply related to the strength of the wind at the inflection.

The height-change pair rotate clockwise with the passage of time. That is, the height rise shifts to the north as it moves eastward, and the fall center shifts to the south. The intensity of the cyclogenesis is related in a general way to the intensity of the height-fall center.

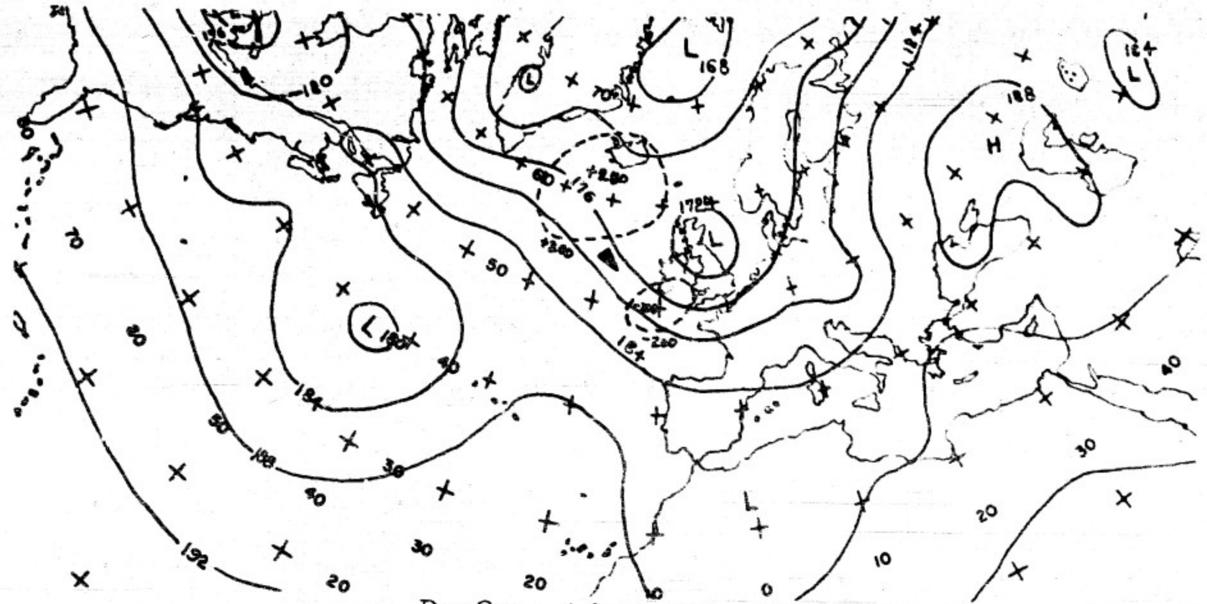
The data for these sixteen cases is listed in the following table which precedes the copies of the 500-mb and surface charts from the historical map series for these examples.

Case No.	DATE	INFLECTION				HEIGHT-CHANGE CENTERS						CYCLOGENESIS					
		Position		Speed	Orien-tation	RISE			FALL			Position		Surf. Pres.	500-mb Height	Pres. Change	Height Change
						Position		Intensity	Position		Intensity						
		Lat.	Long.	(Geo. Kts.)	(Degrees)	Lat.	Long.	(Feet)	Lat.	Long.	(Feet)	Lat.	Long.	(mb)	(Feet)	(mb)	(Feet)
1	4/1/51	54	18W	55	310	61	22W	+280	50	10W	-200						
	4/2/51	50	68W	40	330	56	10W	+550	43	02W	-210	43	02E	1018	815	-3	-250
	4/3/51											43	11E	1013	800	-6	-300
2	3/22/51	62	39W	35	350	73	41W	+550	58	19W	-410						
	3/23/51	56	17W	60	310	49	30W	+550	52	07W	-800	49	10W	1007	815	-12	-720
	3/24/51	54	06W	95	320	48	15W	+700	46	05E	-900	44	07E	998	790	-20	-820
	3/25/51	46	01E	90	350	56	04W	+270	38	10E	-610	42	15E	993	765	-14	-570
3	3/26/51	62	26W	30	320	57	40W	+1040	54	17W	-900						
	3/27/51	61	10W	45	350	58	25W	+750	46	08W	-560	48	00	1005	769	-10	-310
	3/28/51											44	07E	1002	810	-9	-400
4	2/4/51	50	38W	130	300	58	42W	+550	50	10W	-1120						
	2/5/51	49	17W	80	310	48	25W	+810	36	06W	-650	43	02W	987	782	-6	-640
	2/6/51	48	14W	95	315	46	09W	+440	33	03E	-380	35	08E	997	802	-9	-230
	2/7/51											41	14E	993	775	-10	-480
5	12/31/50	57	32W	90	305	61	46W	+390	53	14W	-650						
	1/1/51	50	23W	65	335	56	26W	+420	49	07W	-400	45	13W	1002	750	-6	-300
	1/2/51	48	13W	55	330	54	17W	+590	41	01E	-400	41	01W	993	759	-14	-340
	1/3/51	37	00	100	335	43	08W	+650	31	05E	-600	41	08E	993	755	-5	-120
6	1/11/51	48	31W	80	295	55	41W	+1040	53	15W	-1120						
	1/12/51	46	13W	70	315	55	22W	+840	50	01E	-550	45	06E	1003	772	-13	-510
	1/13/51	44	00	40	310	47	10W	+610	40	14E	-610	38	18E	994	777	-19	-660

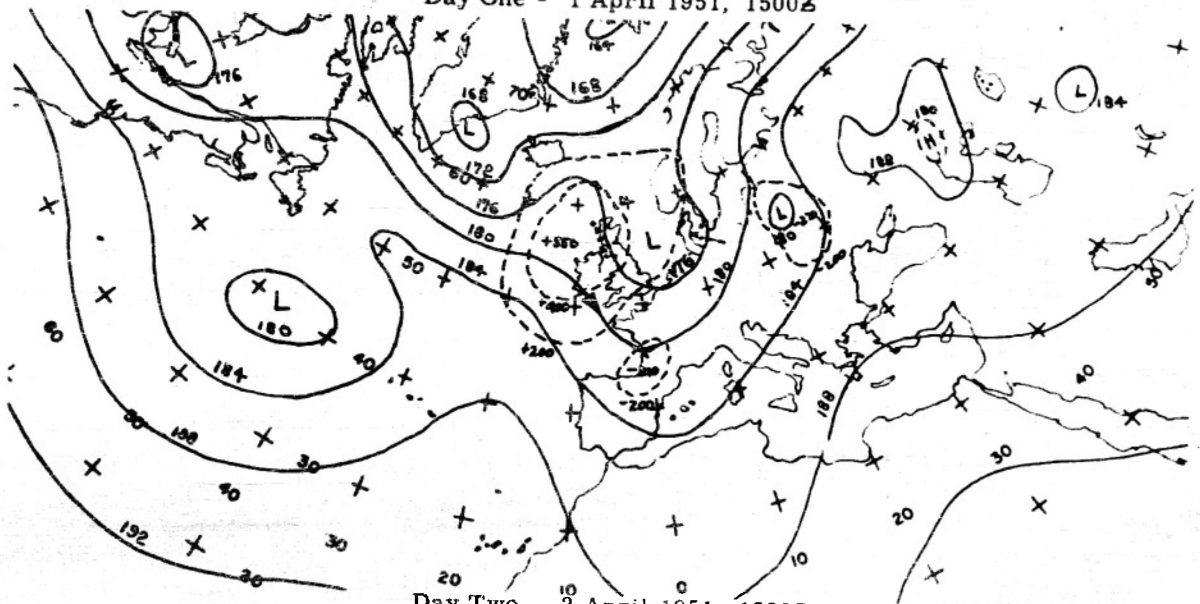
Case No.	DATE	INFLECTION Position Lat.	Long.	Speed (Geo.Kts.)	Orientation (Degrees)	HEIGHT-CHANGE CENTERS RISE Position Lat.	Long.	Intensity (Feet)	FALL Position Lat.	Long.	Intensity (Feet)	CYCLOGENESIS Position Lat.	Long.	Surf. Pres. (mb)	500-mb Height (Feet)	Pres. Change (mb)	Height Change (Feet)
7	1/14/51	54	04W	65	290	60	26W	+630	68	37E	-460						
	1/15/51	51	00	70	320	59	14W	+780	56	27E	-400	47	05E	1007	798	-6	-50
	1/16/51	44	06E	75	005	54	01E	+1000	41	13E	-730	41	17E	997	759	-13	-580
8	1/17/51	55	23W	70	270	48	30W	+850	62	09W	-1000						
	1/18/51	53	06W	70	310	60	30W	+620	53	12E	-750	46	09E	1012	815	-15	-380
	1/19/51	49	05E	65	335	54	05W	+730	45	18E	-600	40	18E	995	788	-18	-300
	1/20/51											41	30E	987	787	-17	-100
9	1/21/51	49	45W	90	295	45	54W	+640	54	17W	-660						
	1/22/51	49	30W	60	320	51	40W	+1240	51	10W	-550	47	20W	1018	778	-5	-380
	1/23/51	46	20W	75	355	55	23W	+1010	43	05E	-600	48	08W	1000	773	-19	-400
	1/24/51											42	04W	1000	757	-12	-610
10	11/28/50	60	21W	35	335	53	36W	+1000	55	04W	-700						
	11/29/50	53	08W	70	330	52	20W	+900	52	10E	-800	47	02E	1013	803	-7	-650
	11/30/50	44	06E	85	355	51	01E	+800	38	10E	-600	43	06E	1002	806	-15	-350
11	10/17/50	56	01W	100	290	64	20W	+400	61	17W	-500						
	10/18/50	56	09E	90	315	62	04W	+700	55	23E	-800	54	25E	999	767	-19	-760
	10/19/50	52	17E	55	005	58	14E	+800	43	30E	-600	51	35E	990	760	-17	-290
12	4/1/50	57	30W	100	290	55	52W	+1260	60	21W	-1010						
	4/2/50	52	10W	65	335	60	22W	+1200	53	03E	-1080	48	02E	1000	760	-17	-650
	4/3/50	44	01W	70	355	56	01W	+600	43	06E	-640	44	11E	987	740	-16	-630
	4/4/50											42	17E	986	758	-9	-200

Case No.	DATE	INFLECTION Position Lat.	Long.	Speed (Geo. Kts.)	Orientation (Degrees)	HEIGHT-CHANGE CENTERS RISE Position Lat.	Long.	Intensity (Feet)	FALL Position Lat.	Long.	Intensity (Feet)	CYCLOGENESIS Position Lat.	Long.	Surf. Pres. (mb)	500-mb Height (Feet)	Pres. Change (mb)	Height Change Feet)
13	4/4/50	48	57W	80	280	44	69W	+360	53	47W	-800						
	4/5/50	48	47W	100	300	49	58W	+460	49	38W	-800	42	32W	1013	820	-9	-400
	4/6/50	40	35W	55	350	50	41W	+820	38	28W	-480	42	22W	990	780	-25	-450
14	2/5/50	47	24W	90	285	59	28W	+350	53	07E	-520						
	2/6/50	45	02W	70	310	49	18W	+1150	49	09E	-500	43	07E	1008	777	-10	-430
	2/7/50											43	15E	1008	790	-7	-120
15	2/12/50	51	28W	40	325	53	40W	+600	49	20W	-780						
	2/13/50	44	15W	70	315	50	20W	+750	48	01W	-620	49	05W	988	717	-16	-530
	2/14/50	40	04W	60	335	49	07W	+700	34	05E	-640	44	12E	1003	775	-14	-350
16	1/15/50	58	22W	40	310	57	32W	+610	60	04W	-820						
	1/16/50	54	13W	80	340	64	20W	+880	48	01E	-820	53	02E	1011	757	-6	-600
	1/17/50	46	03W	60	005	61	01E	+810	42	08E	-930	45	10E	1004	738	-17	-860

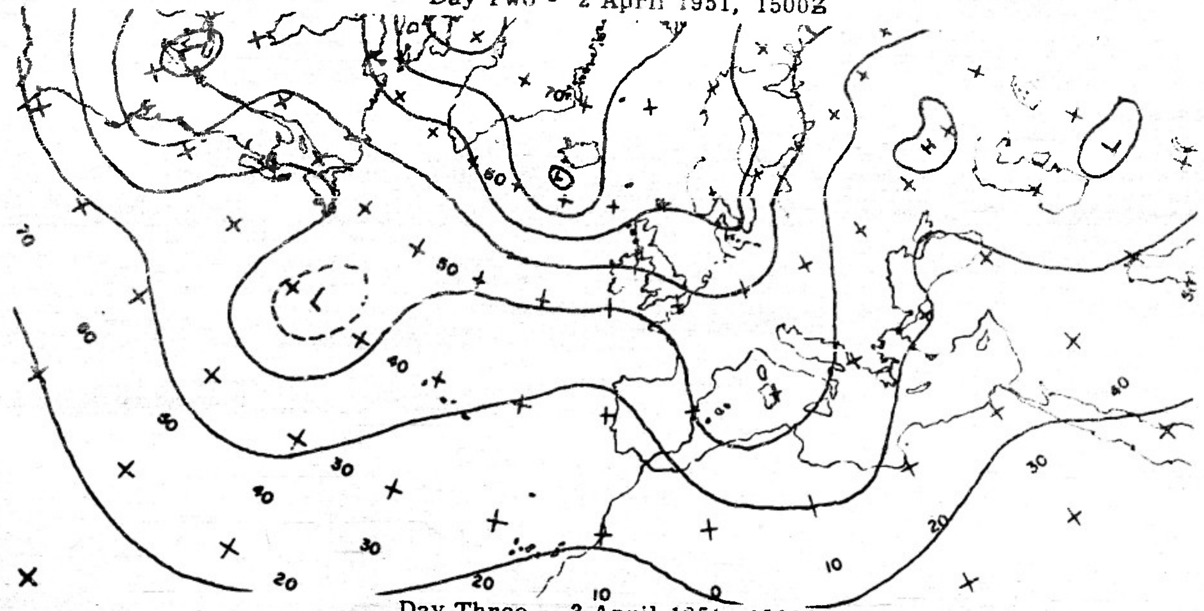
CASE NO. 1
500-Millibar Charts



Day One - 1 April 1951, 1500Z

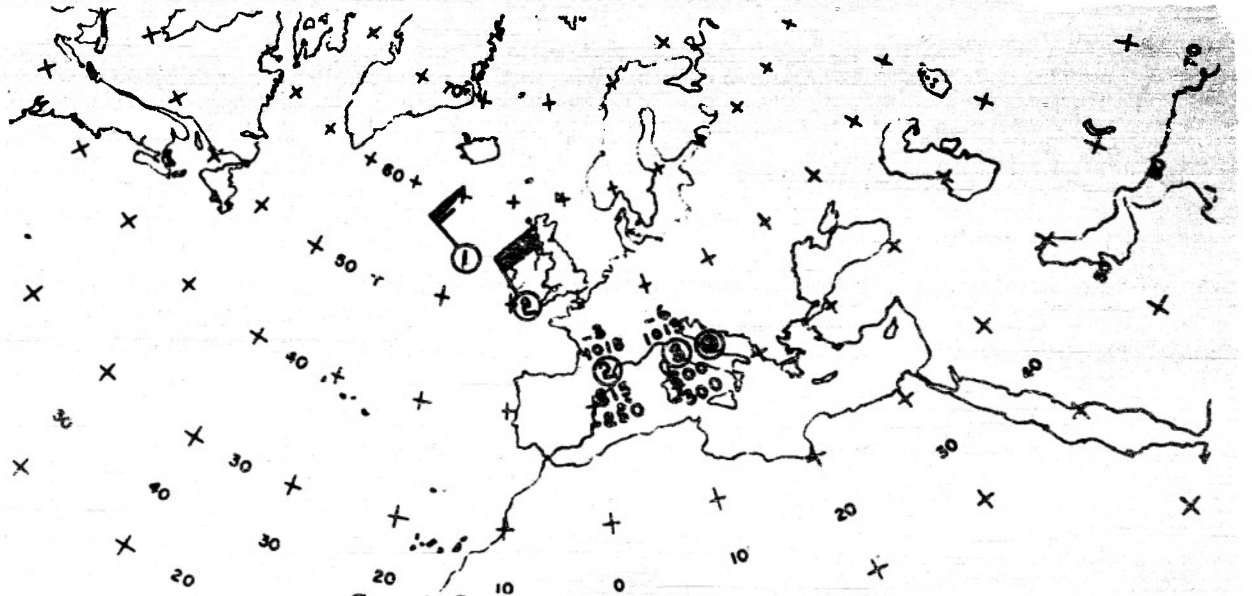


Day Two - 2 April 1951, 1500Z

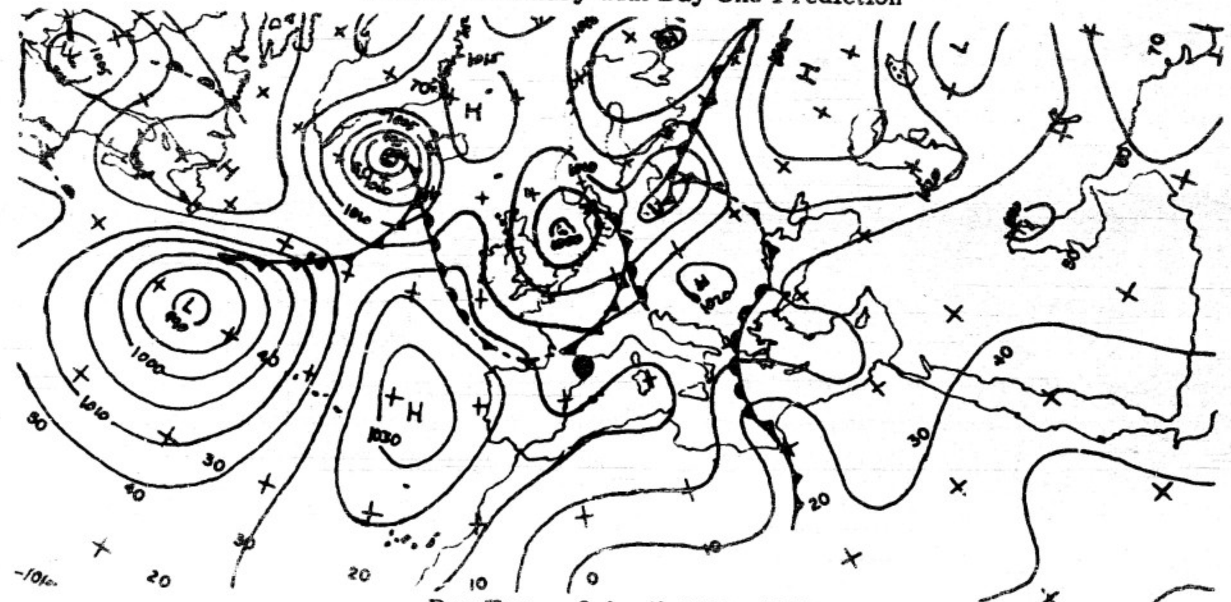


Day Three - 3 April 1951, 1500Z

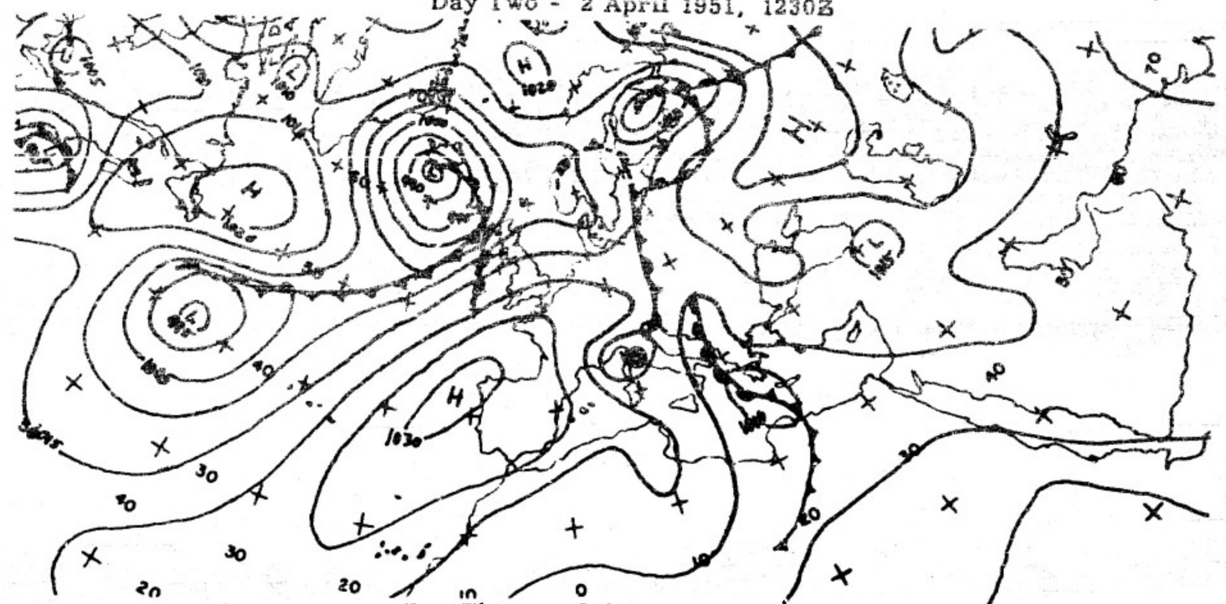
CASE NO. 1
Surface Charts



Case 1 Summary with Day One Prediction

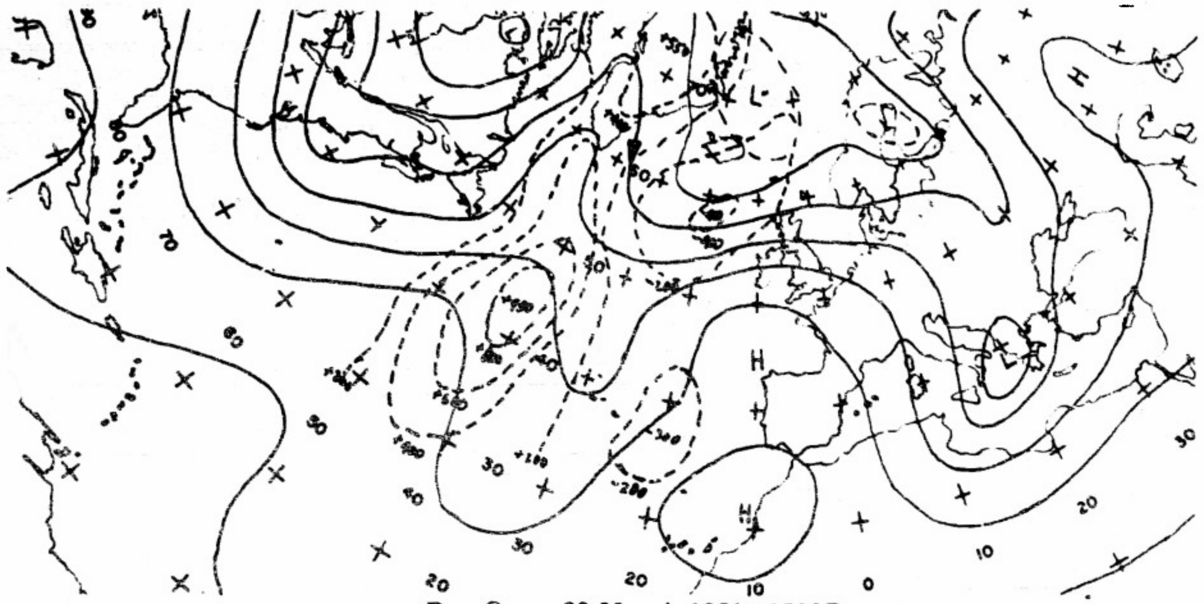


Day Two - 2 April 1951, 1230Z

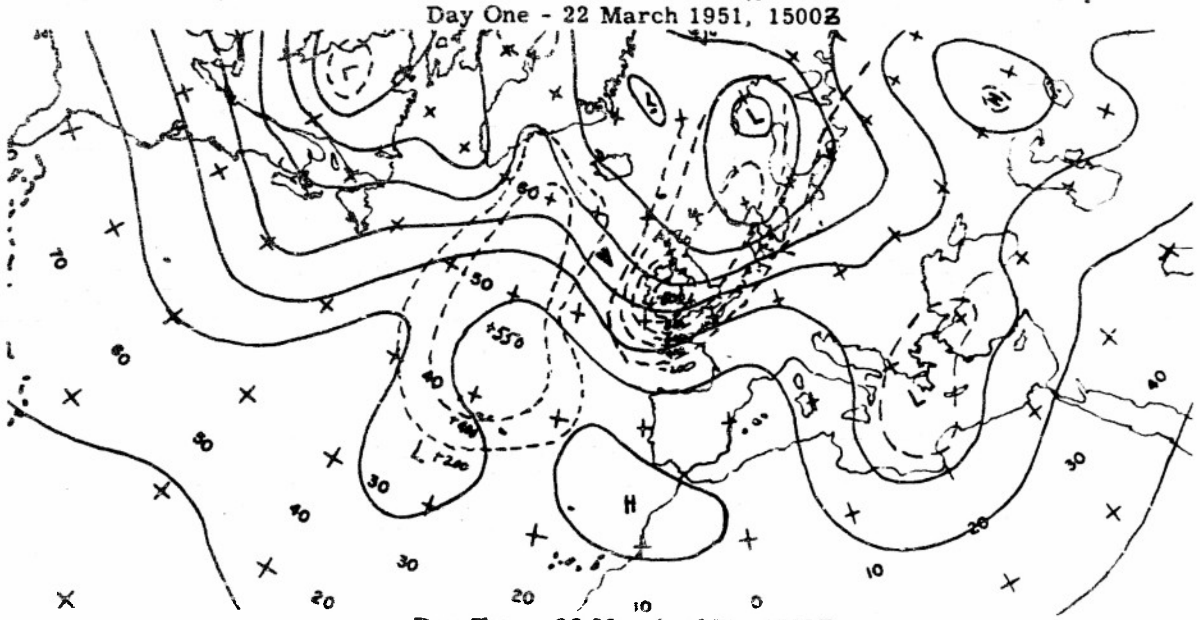


Day Three - 3 April 1951, 1230Z

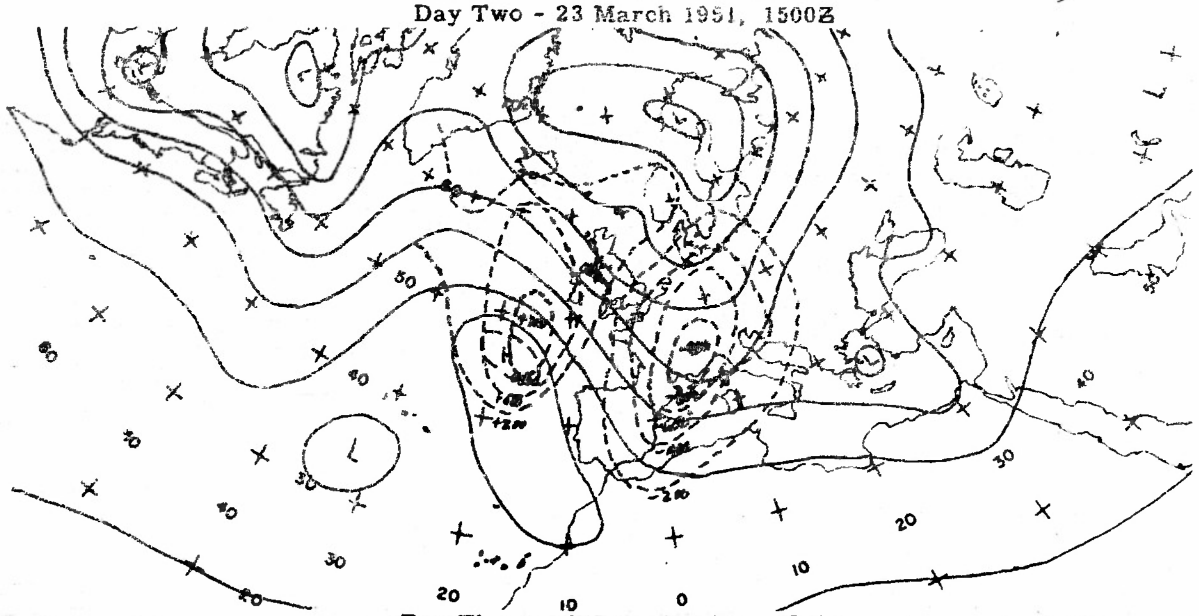
CASE NO. 2
500-Millibar Charts



Day One - 22 March 1951, 1500Z



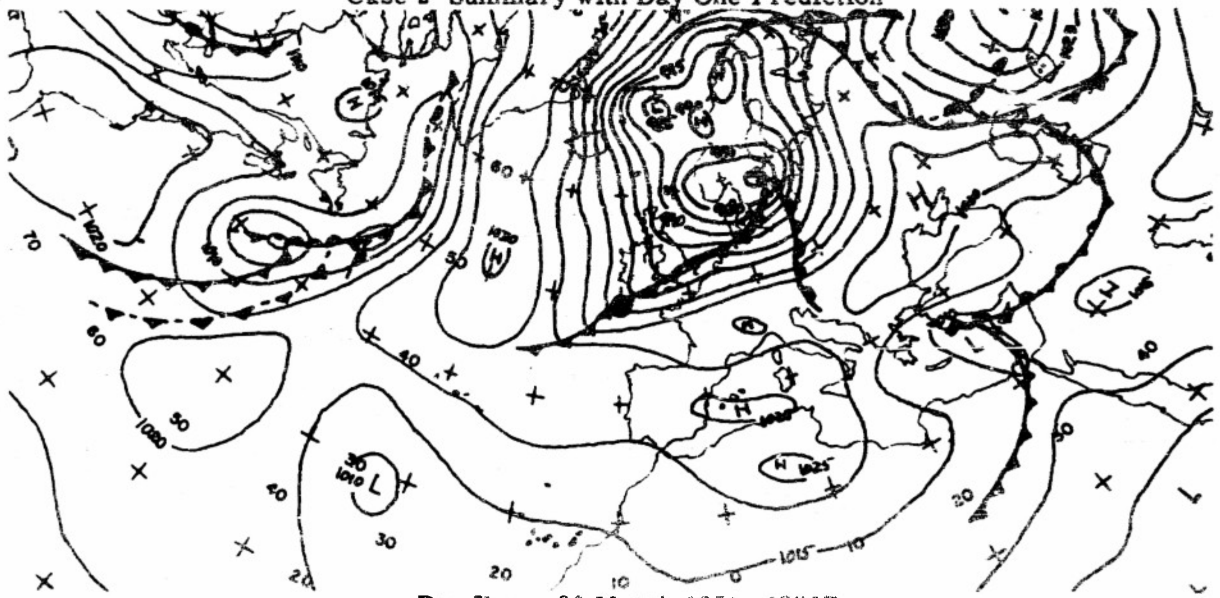
Day Two - 23 March 1951, 1500Z



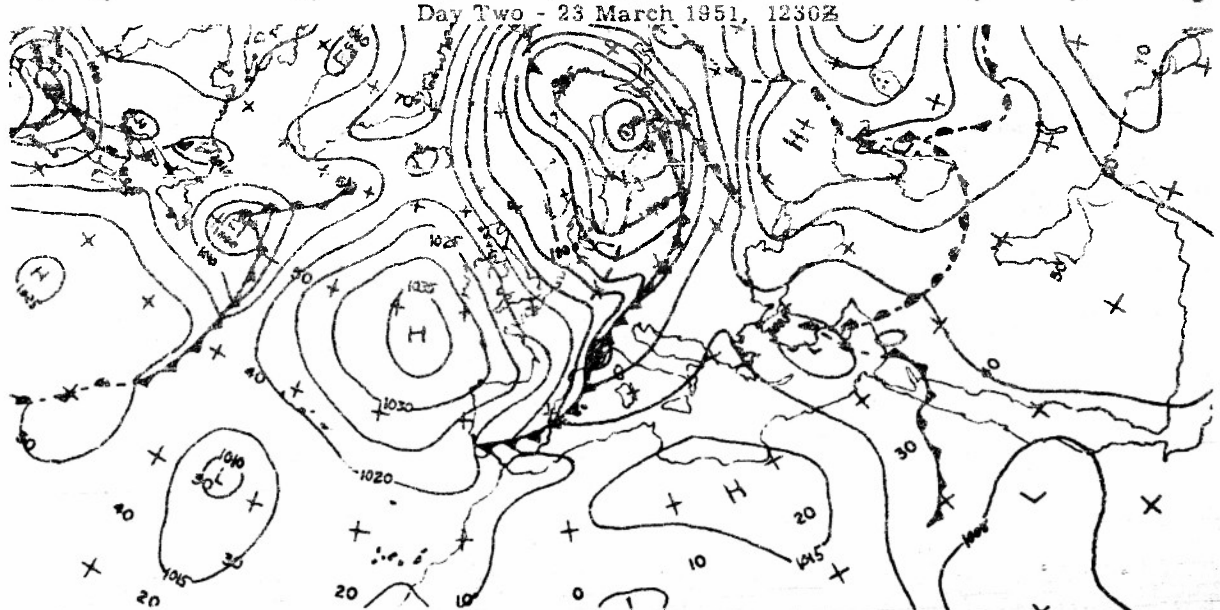
Day Three - 24 March 1951, 1500Z

CASE NO. 2
Surface Charts

Case 2 Summary with Day One Prediction

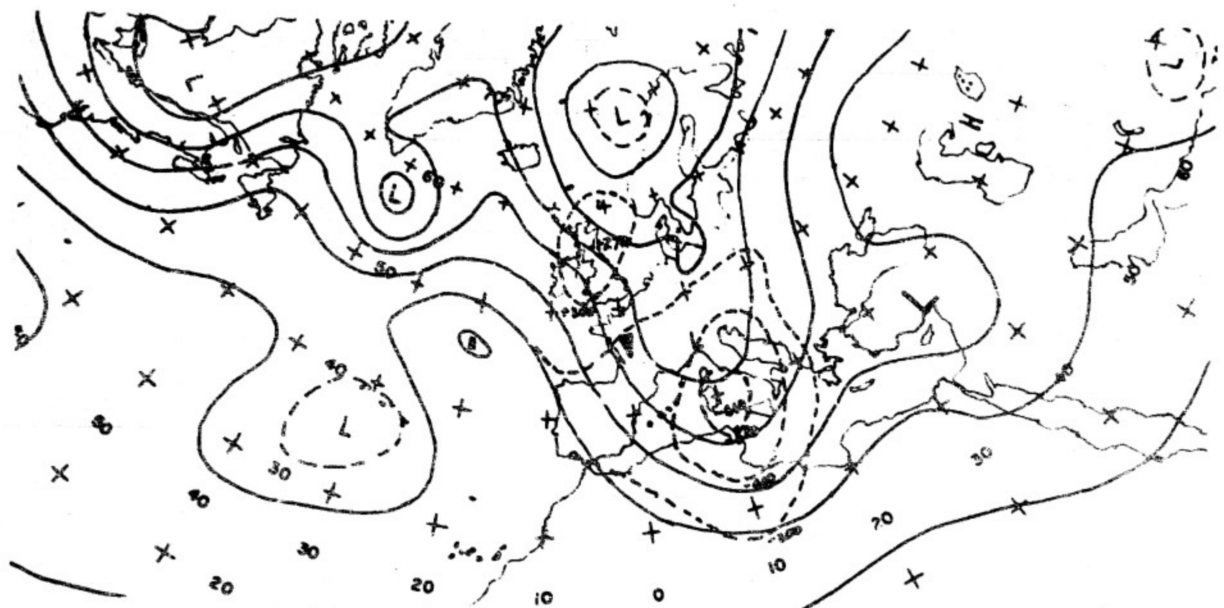


Day Two - 23 March 1951, 1230Z



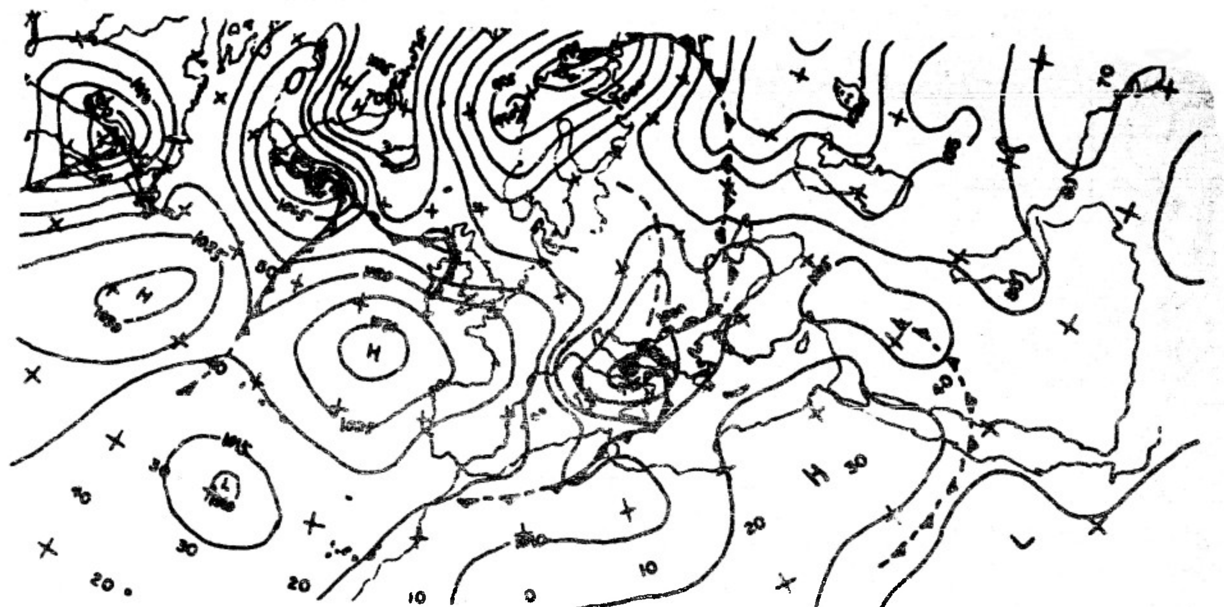
Day Three - 24 March 1951, 1230Z

CASE NO. 2
500-Millibar Charts



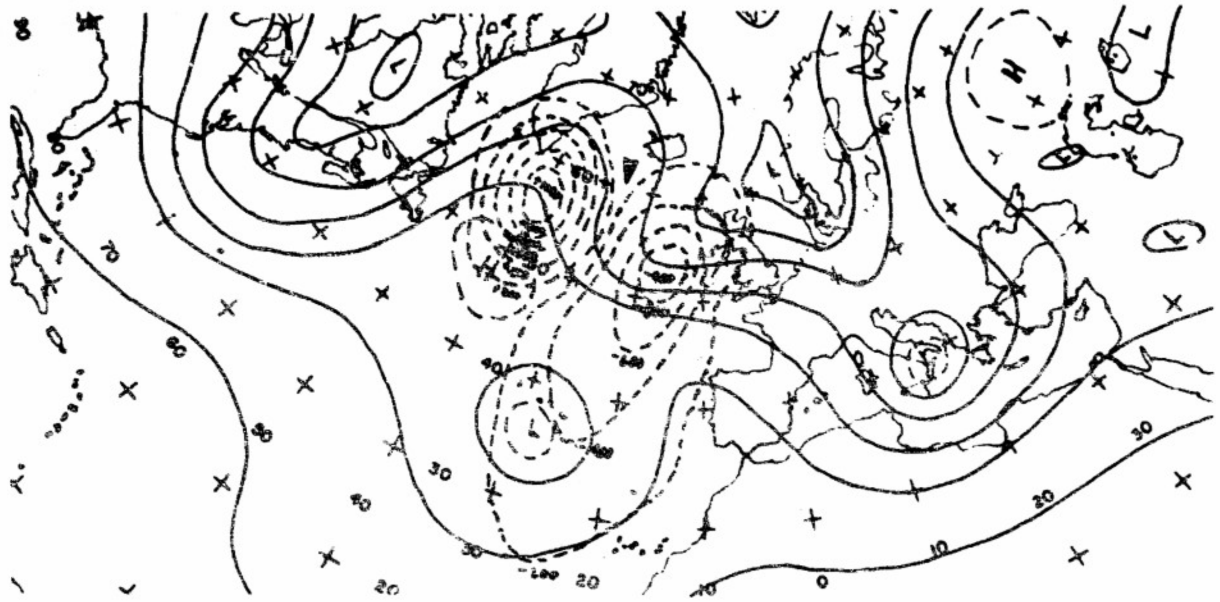
Day Four - 25 March 1951, 1500Z

CASE NO. 2
Surface Charts

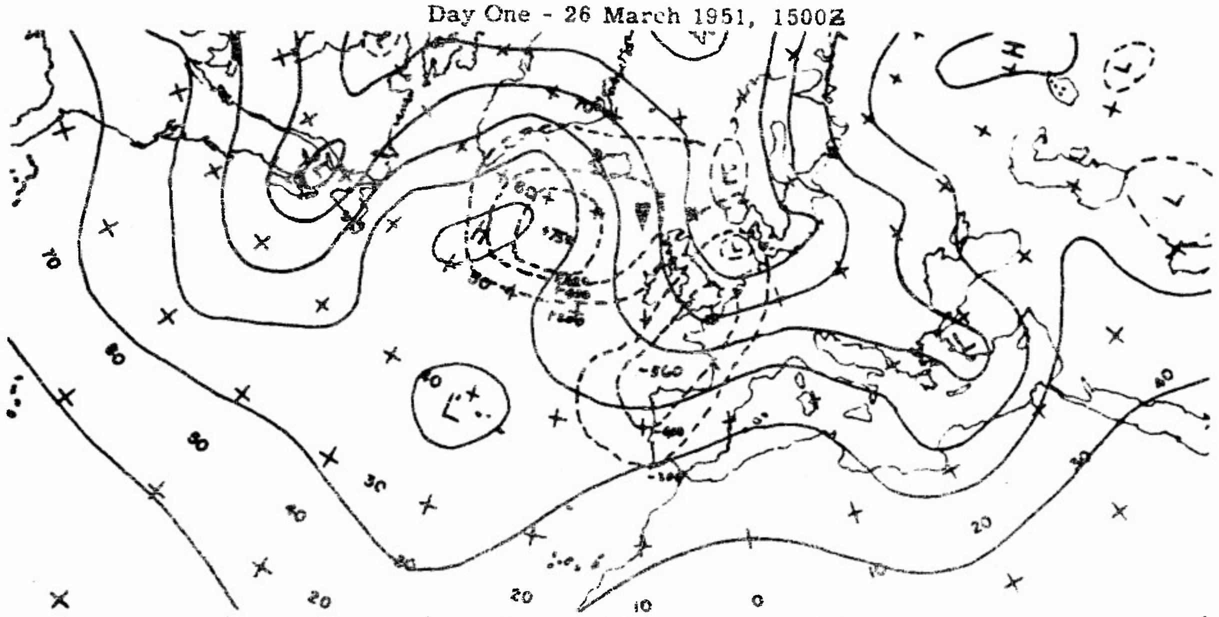


Day Four - 25 March 1951, 1230Z

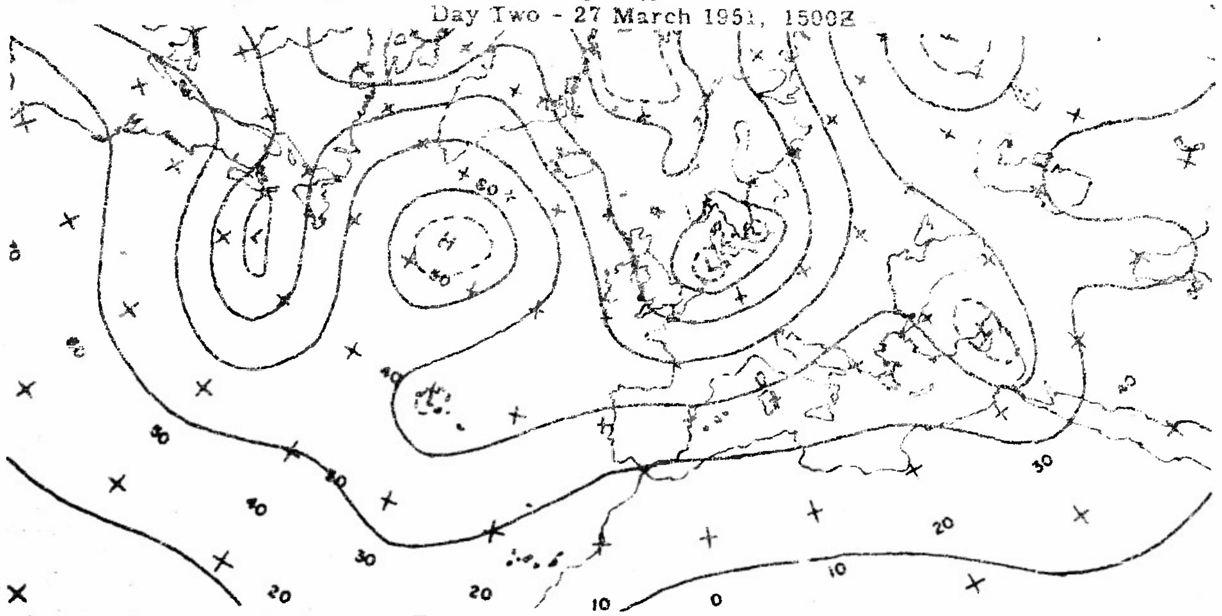
CASE NO. 3
500-Millibar Charts



Day One - 26 March 1951, 1500Z

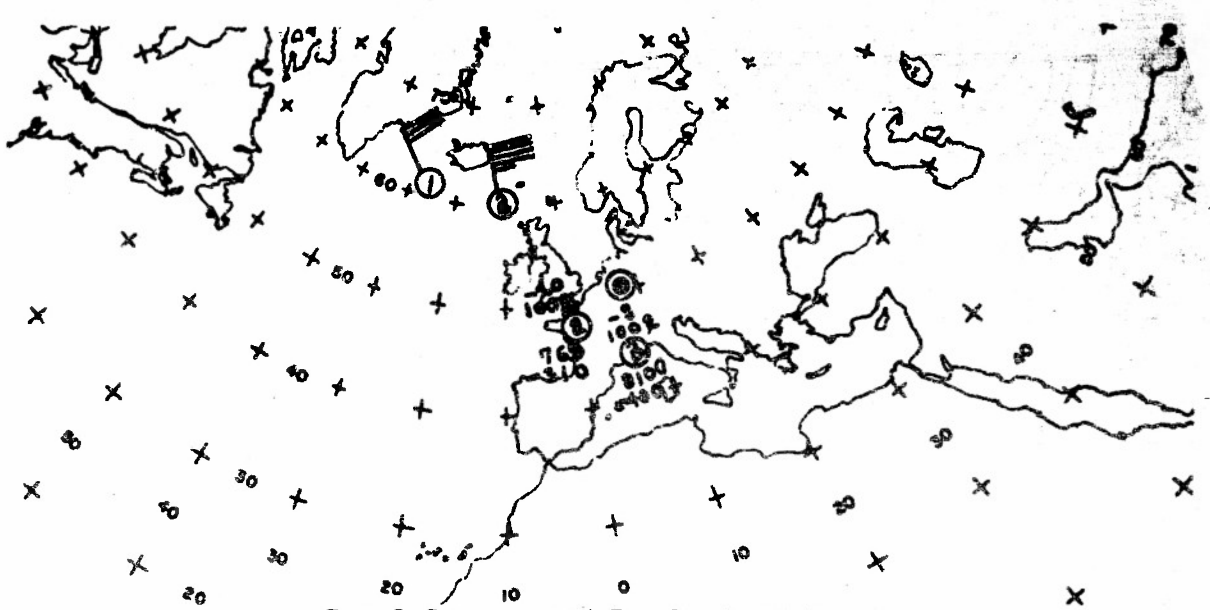


Day Two - 27 March 1951, 1500Z



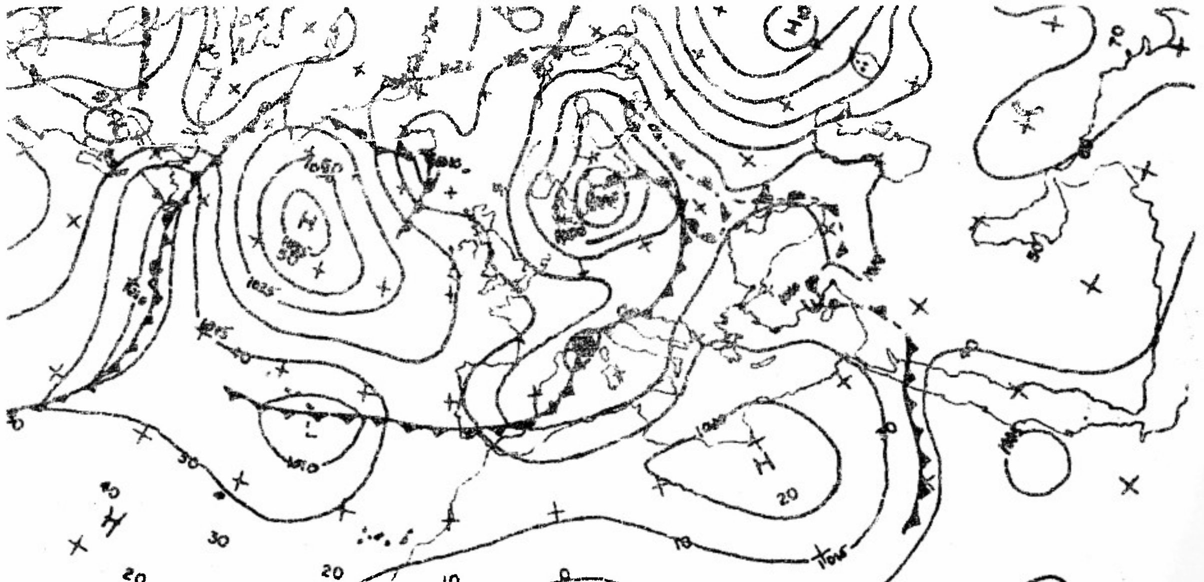
Day Three - 28 March 1951, 1500Z

CASE NO. 3
Surface Charts



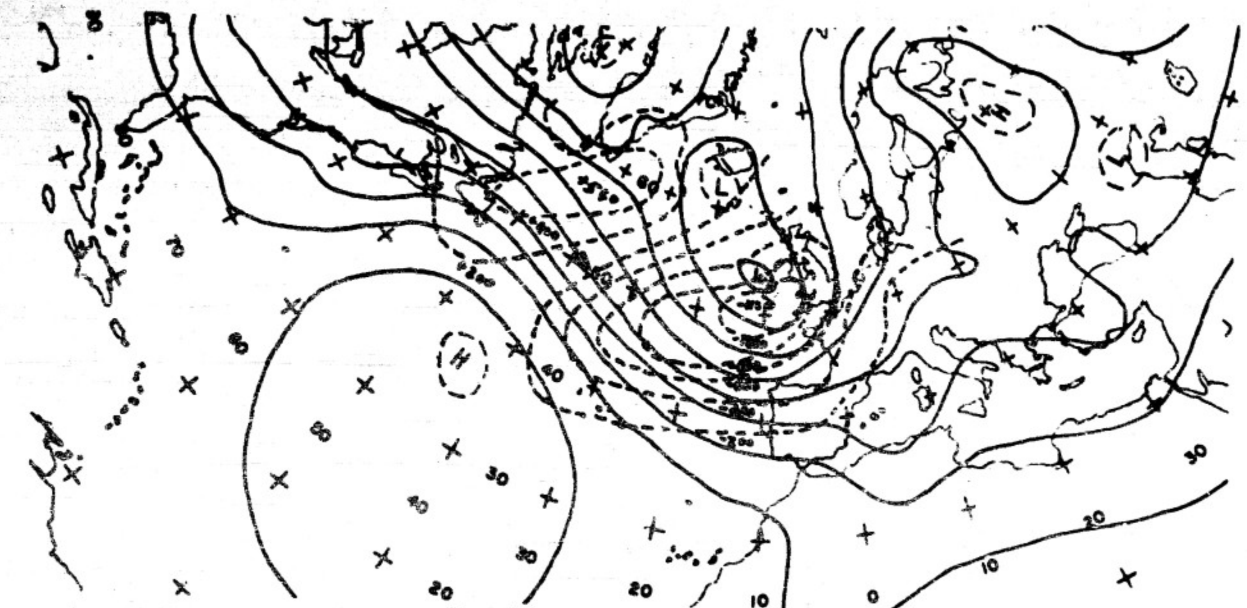
Case 3 Summary with Day One Prediction

Day Two - 27 March 1951, 1230Z

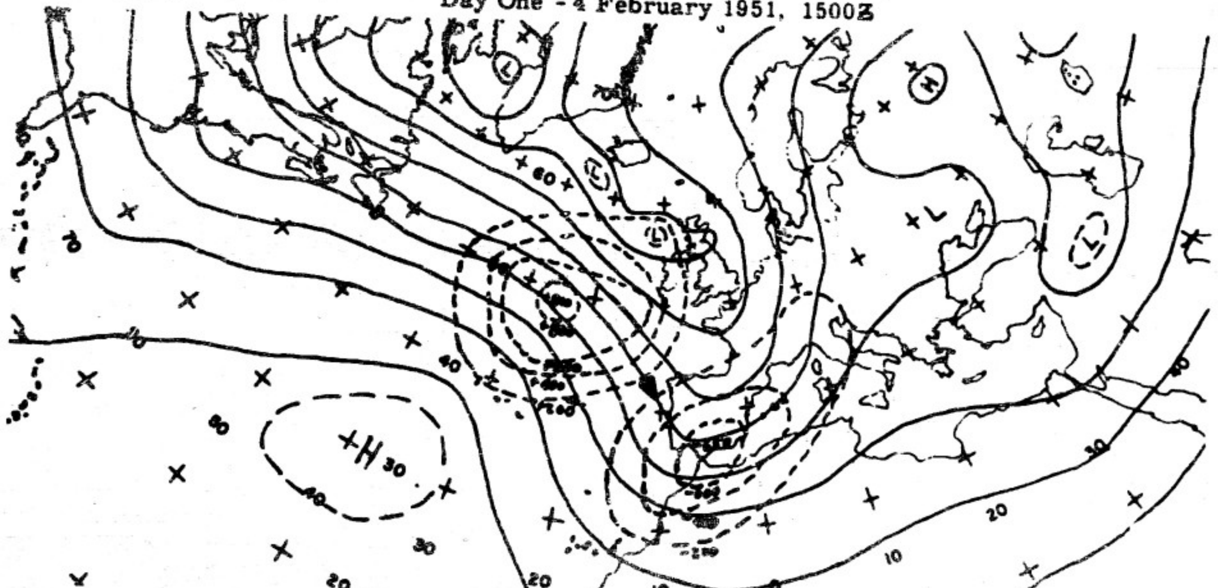


Day Three - 28 March 1951, 1230Z

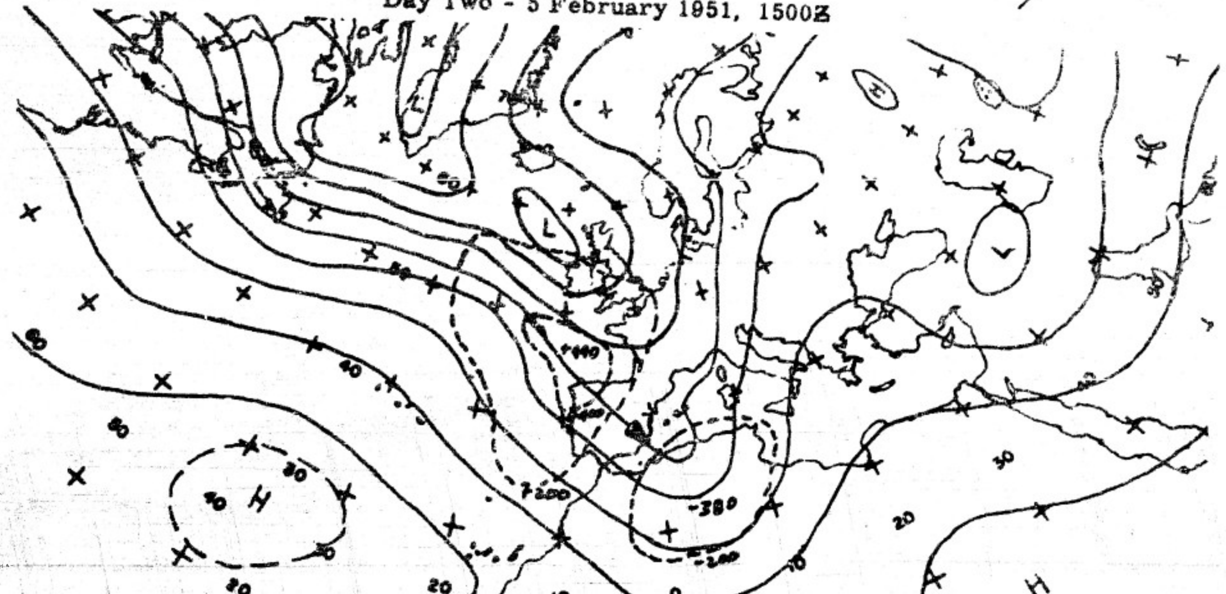
CASE NO. 4
500-Millibar Charts



Day One - 4 February 1951, 1500Z

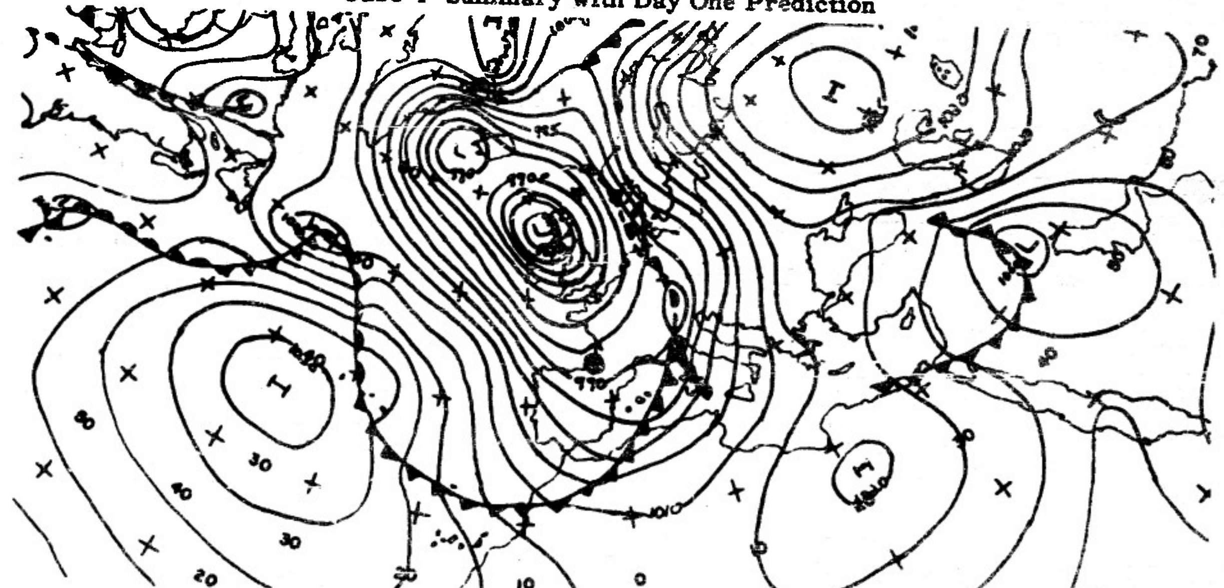


Day Two - 5 February 1951, 1500Z

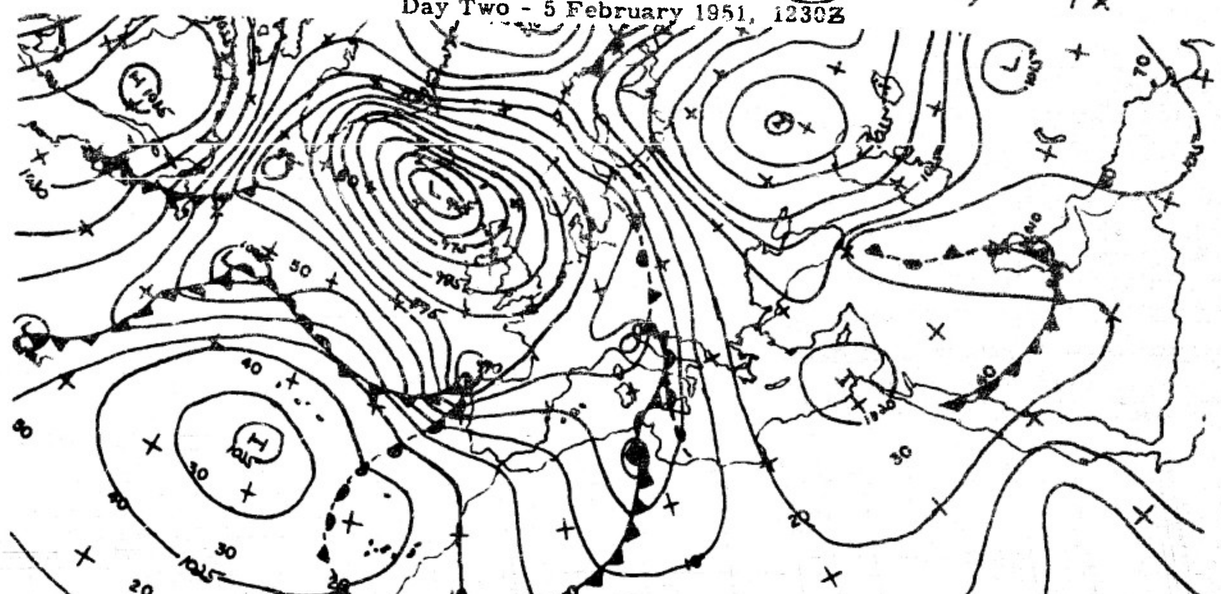


Day Three - 6 February 1951, 1500Z

Case 4 Summary with Day One Prediction

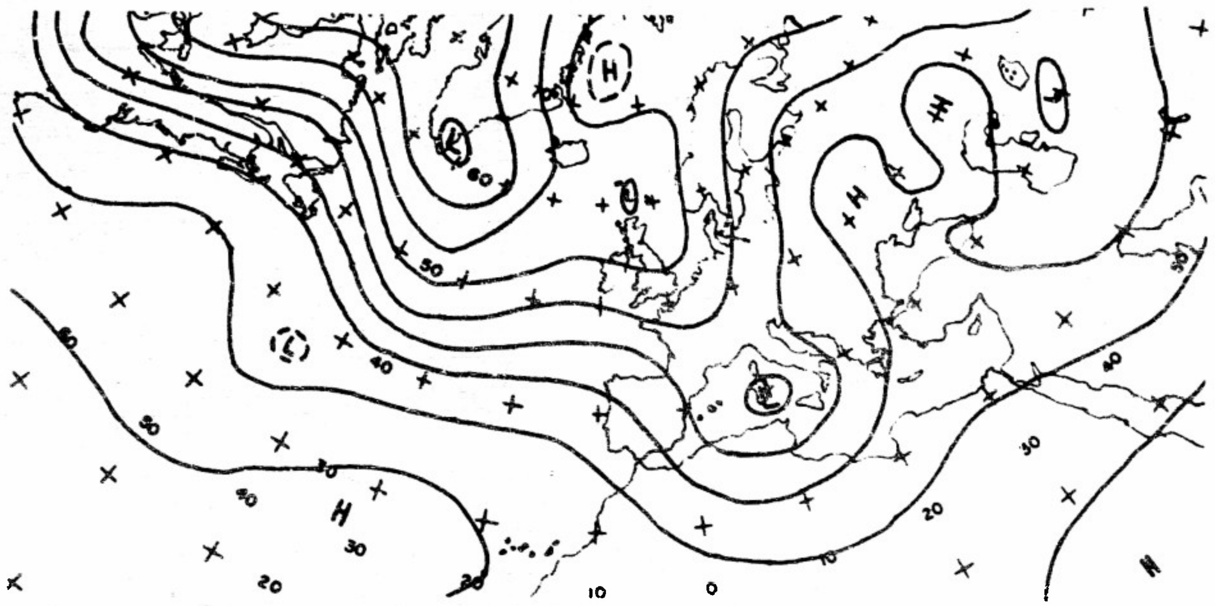


Day Two - 5 February 1951, 1230Z



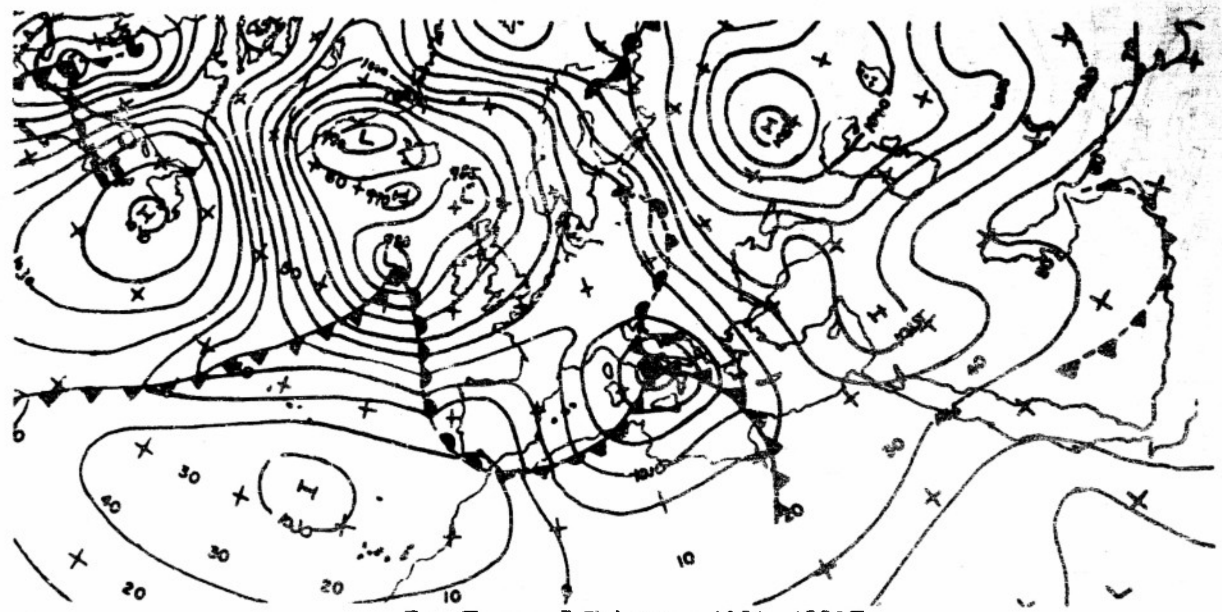
Day Three - 6 February 1951, 1230Z

CASE NO. 4
500-Millibar Charts



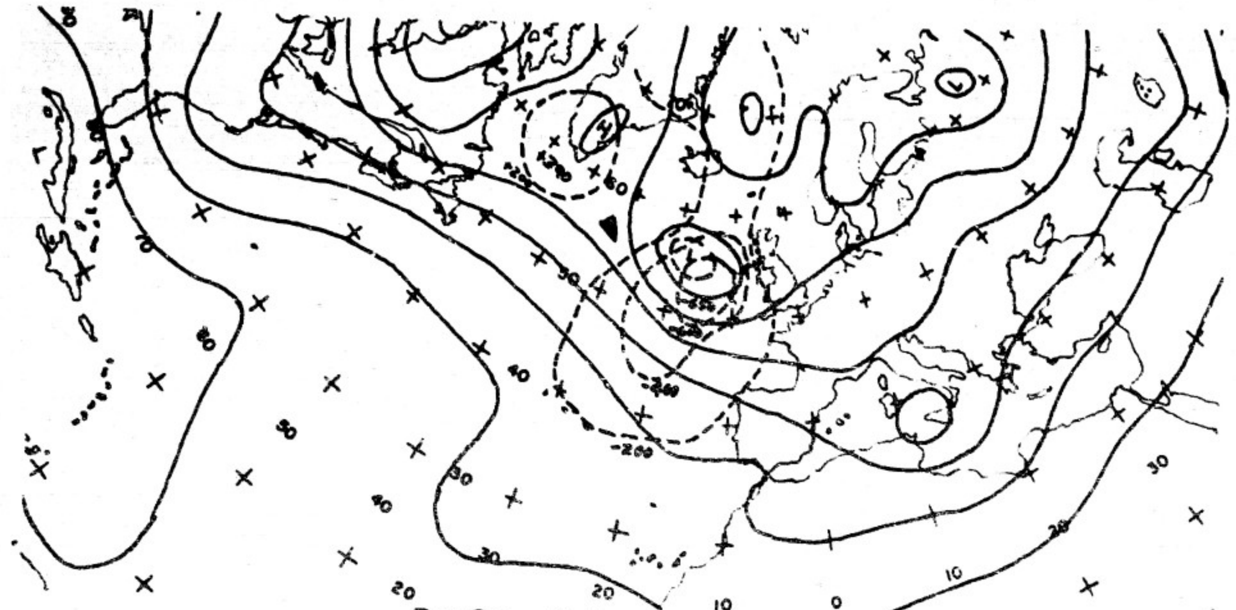
Day Four - 7 February 1951, 1500Z

CASE NO. 4
Surface Charts

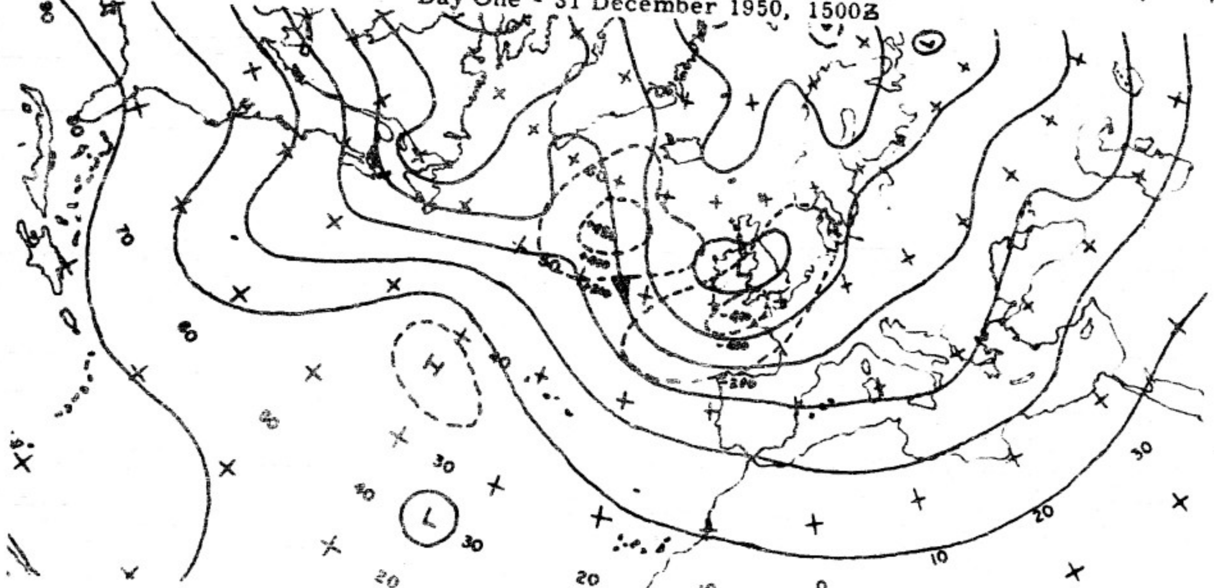


Day Four - 7 February 1951, 1230Z

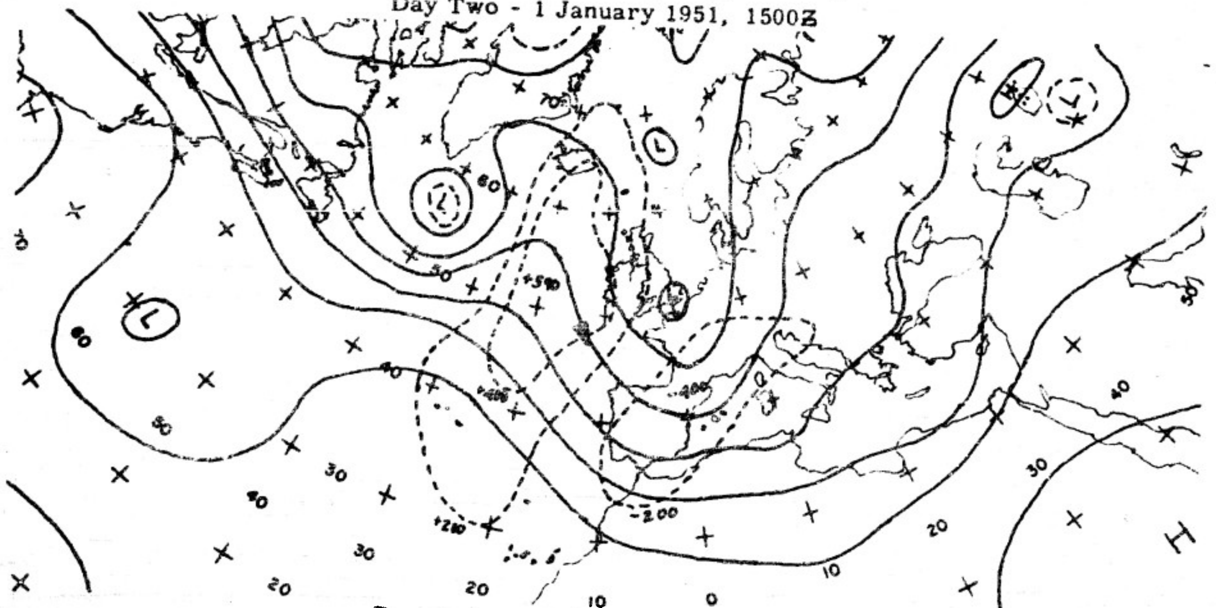
CASE NO. 5
500-Millibar Charts



Day One - 31 December 1950, 1500Z



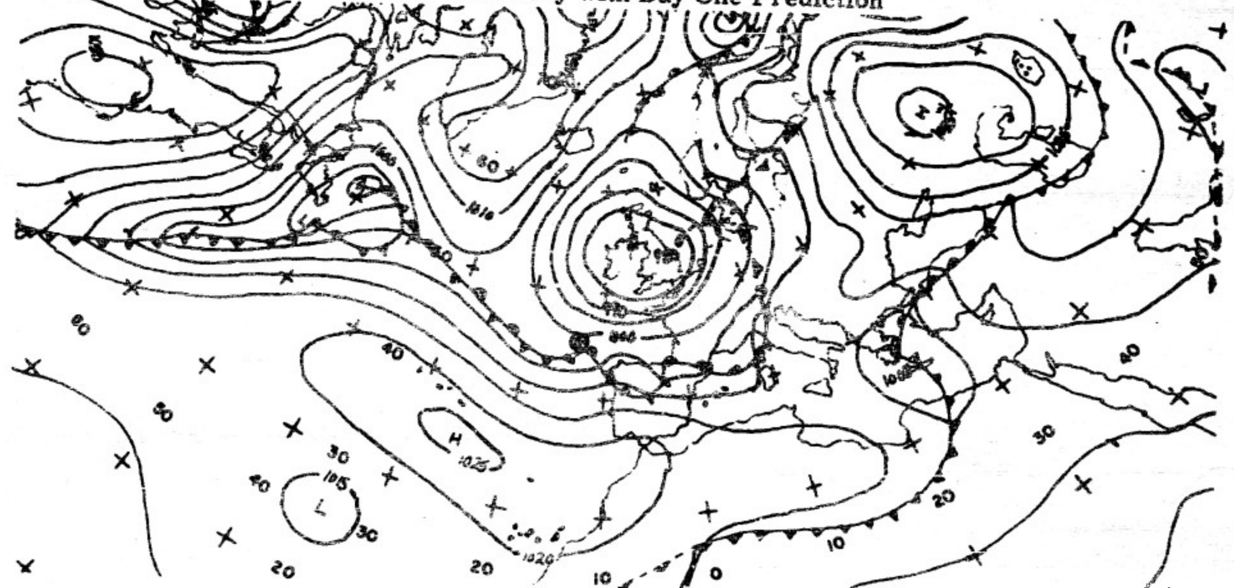
Day Two - 1 January 1951, 1500Z



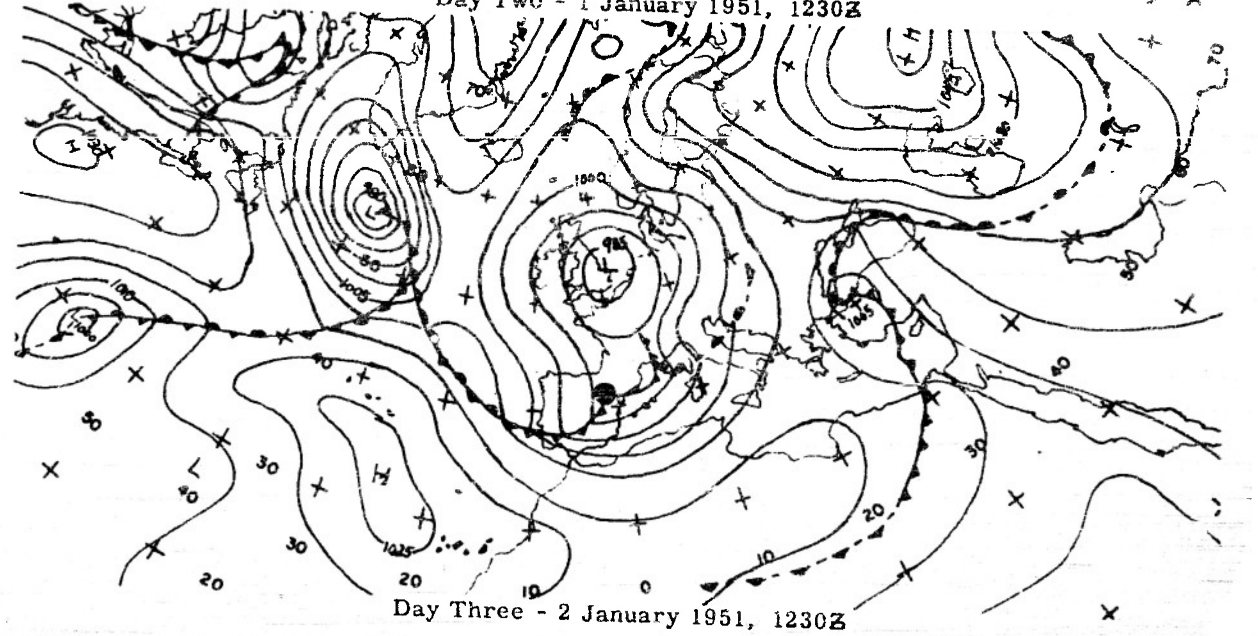
Day Three - 2 January 1951, 1500Z

CASE NO. 5
Surface Charts

Case 5 Summary with Day One Prediction

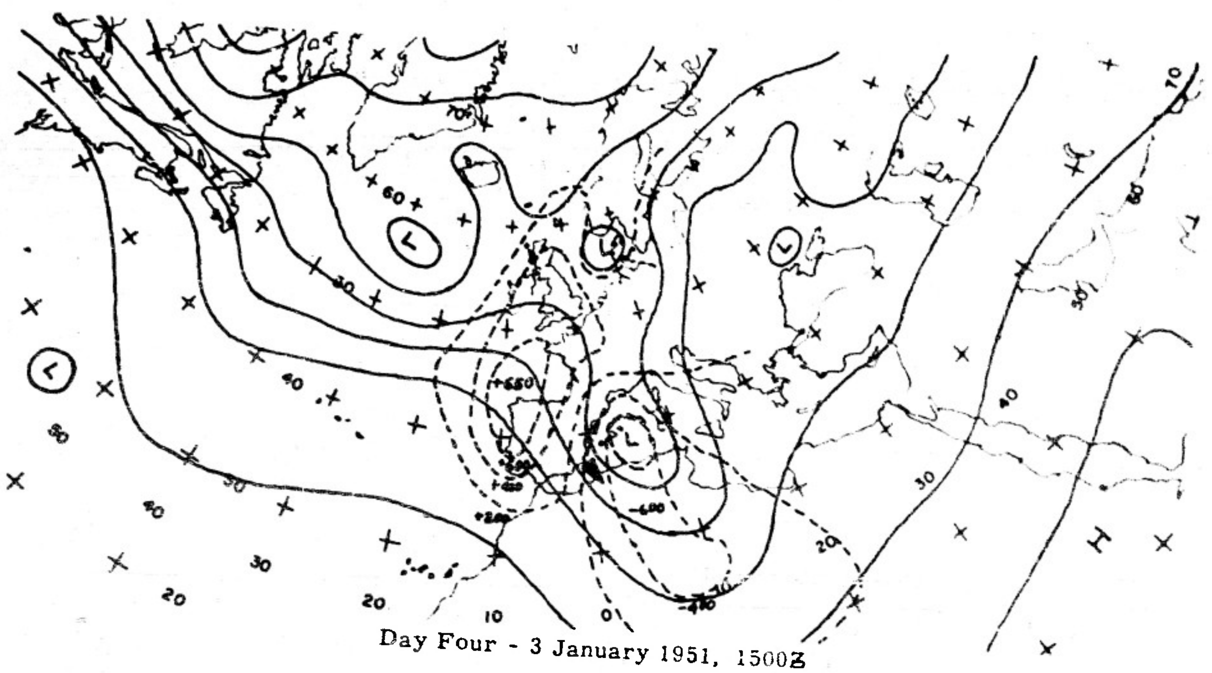


Day Two - 1 January 1951, 1230Z



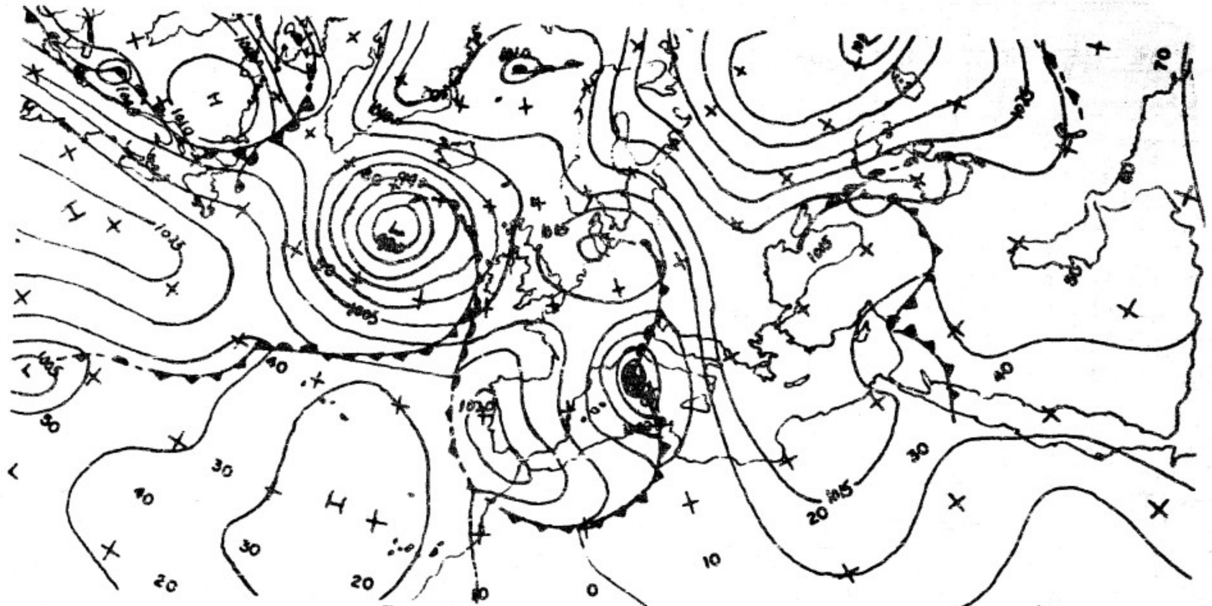
Day Three - 2 January 1951, 1230Z

CASE NO. 5
500-Millibar Charts



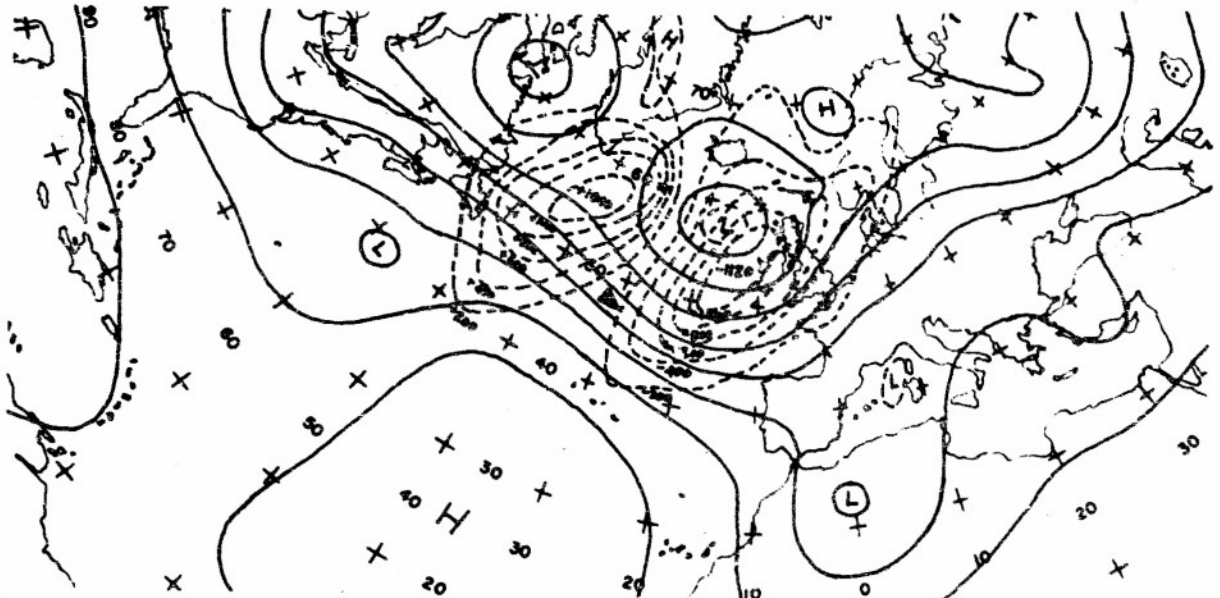
Day Four - 3 January 1951, 1500Z

CASE NO. 5
Surface Charts

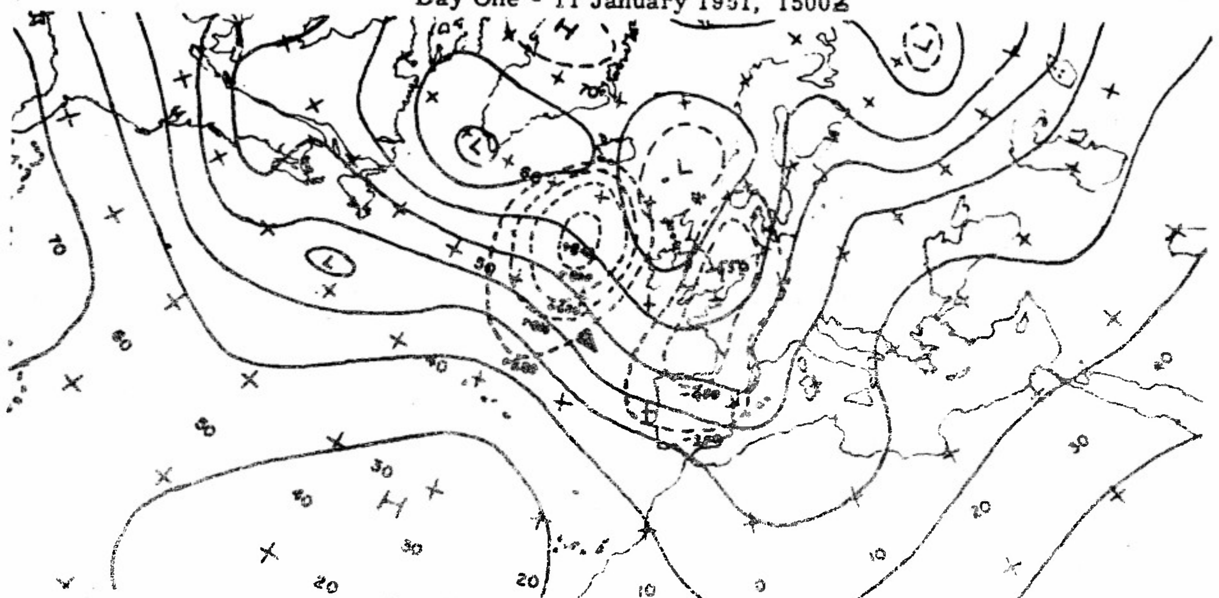


Day Four - 3 January 1951, 1230Z

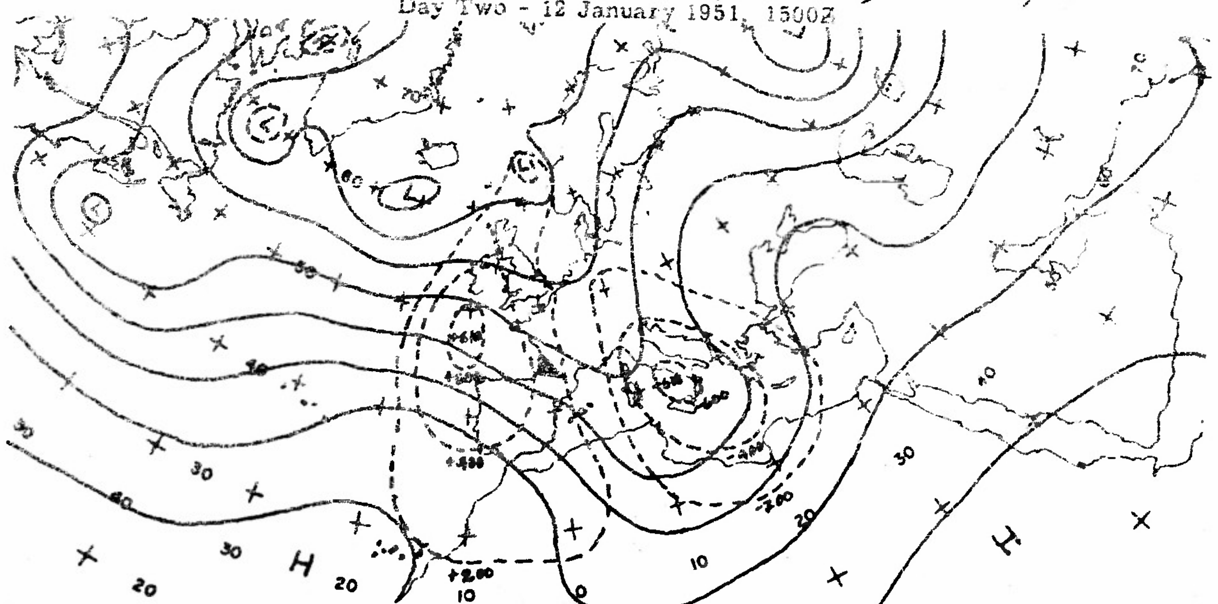
CASE NO. 6
500-Millibar Charts



Day One - 11 January 1951, 1500Z

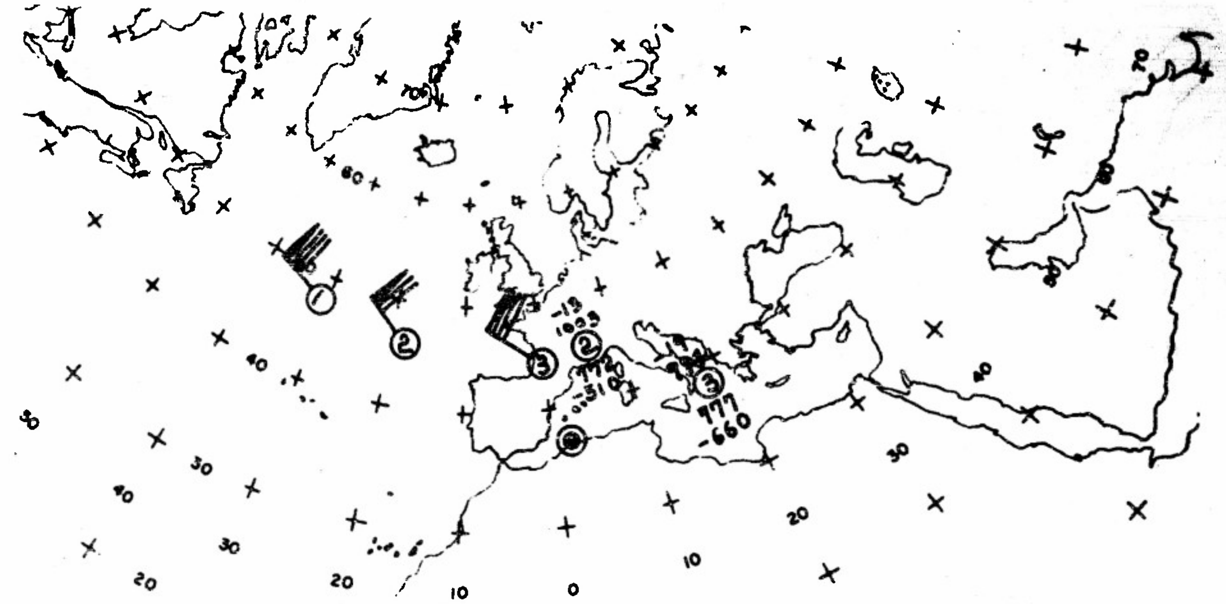


Day Two - 12 January 1951, 1500Z

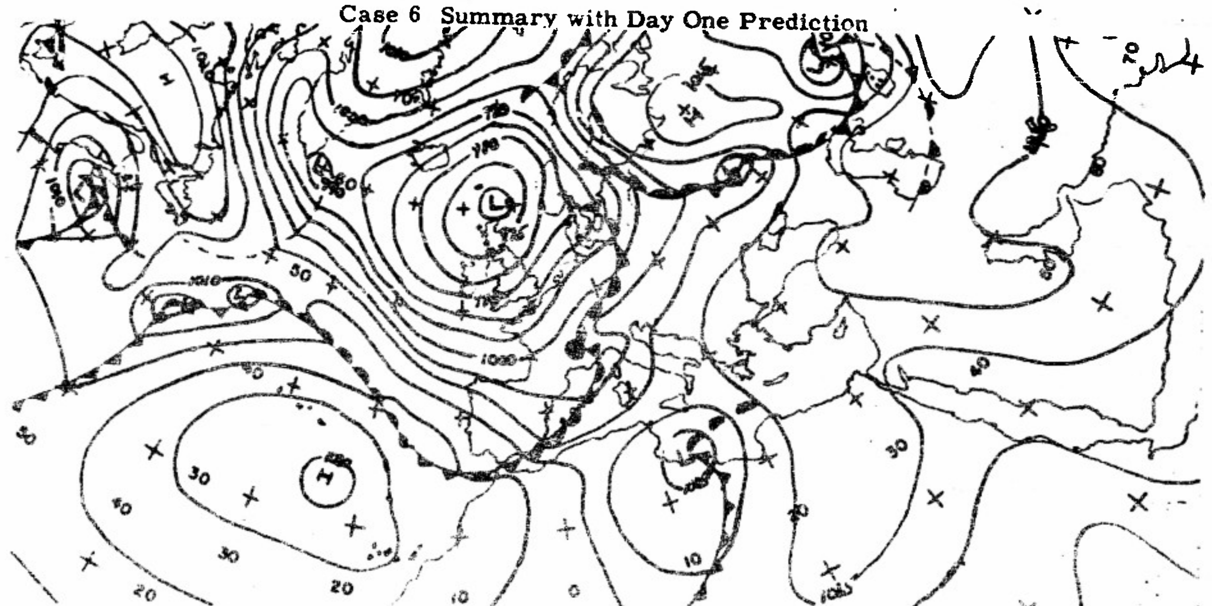


Day Three - 13 January 1951, 1500Z

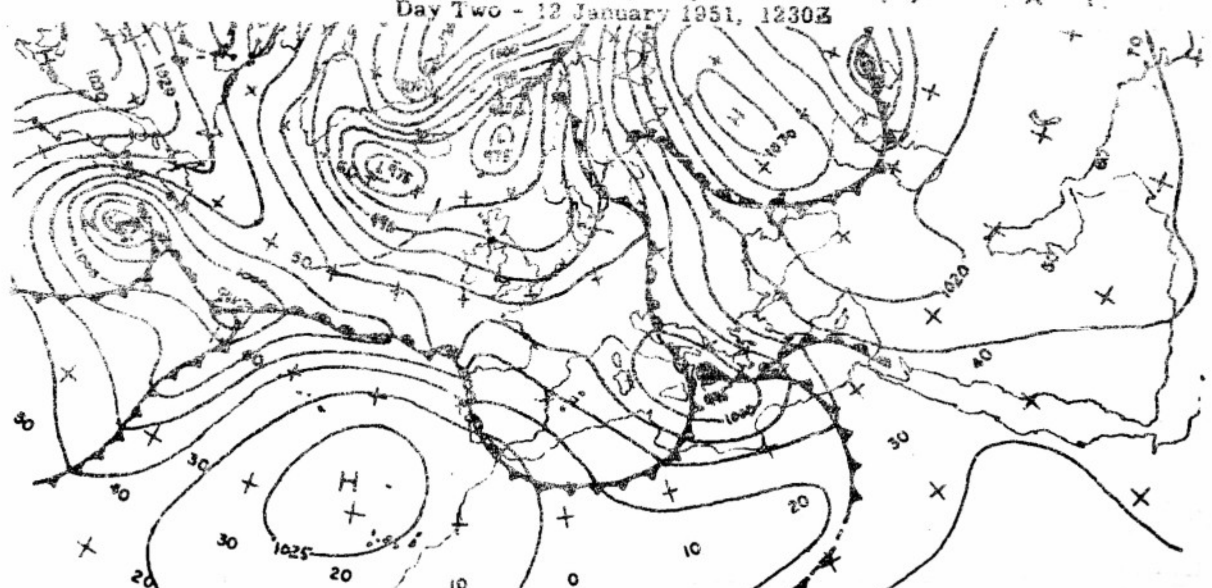
CASE NO. 6
Surface Charts



Case 6 Summary with Day One Prediction

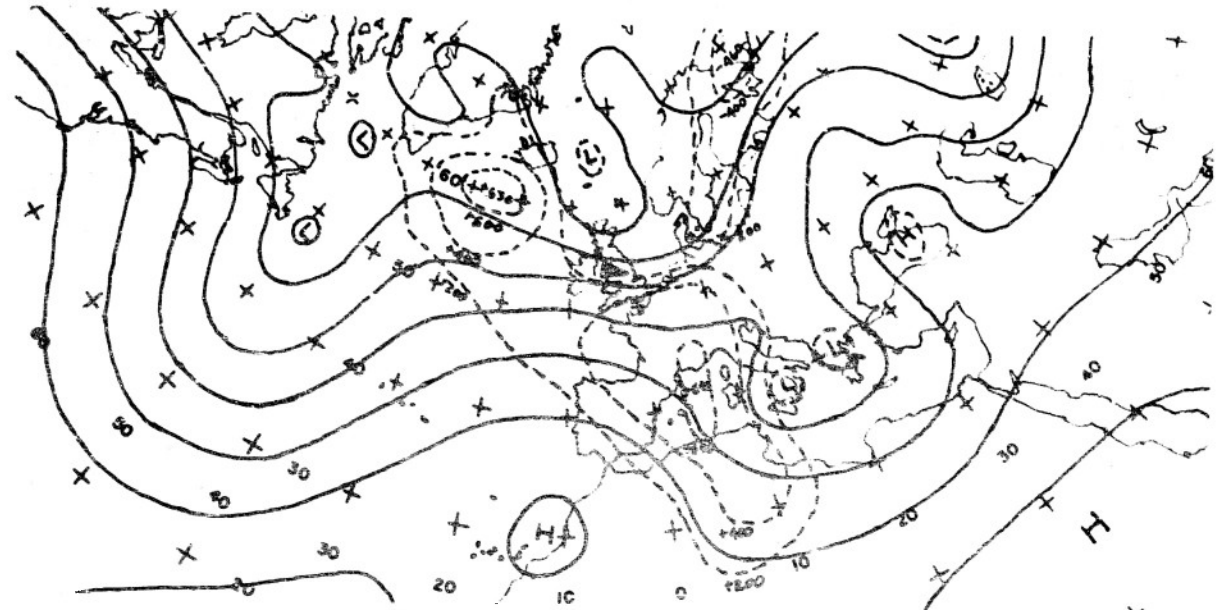


Day Two - 12 January 1951, 1230Z

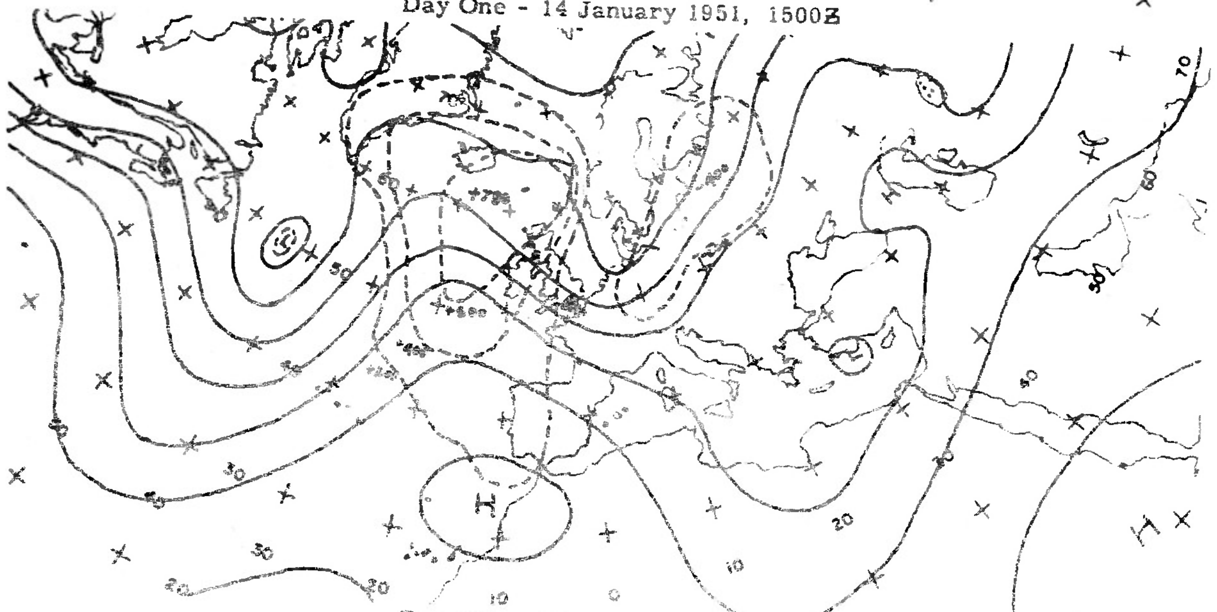


Day Three - 13 January, 1230Z

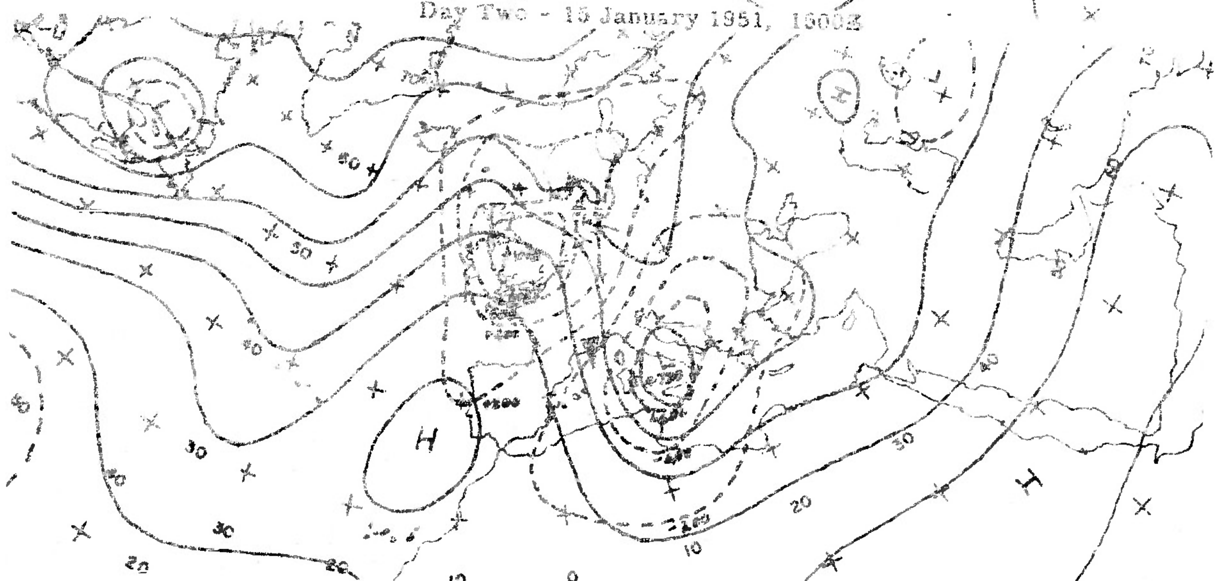
CASE NO. 7
500-Millibar Charts



Day One - 14 January 1951, 1500Z

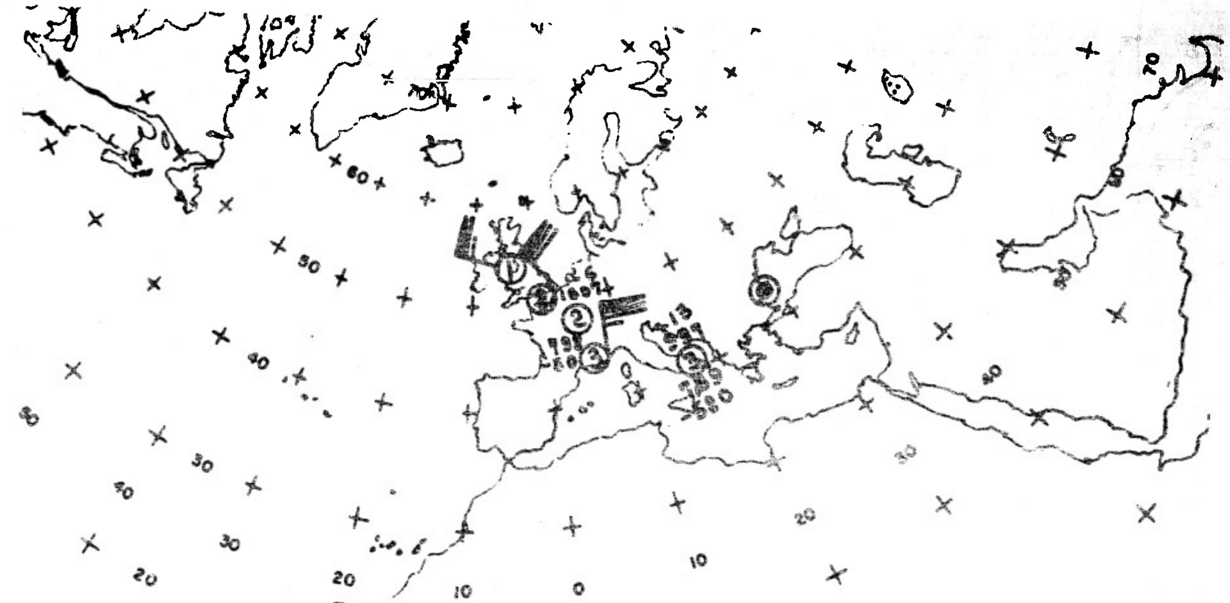


Day Two - 15 January 1951, 1500Z

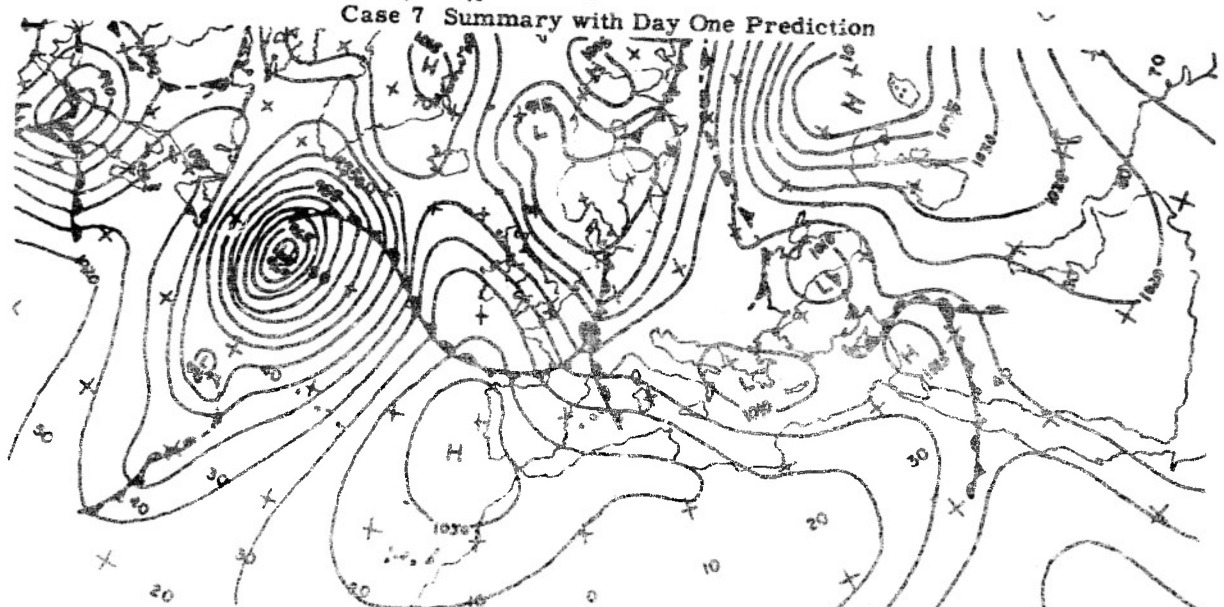


Day Three - 16 January 1951, 1500Z

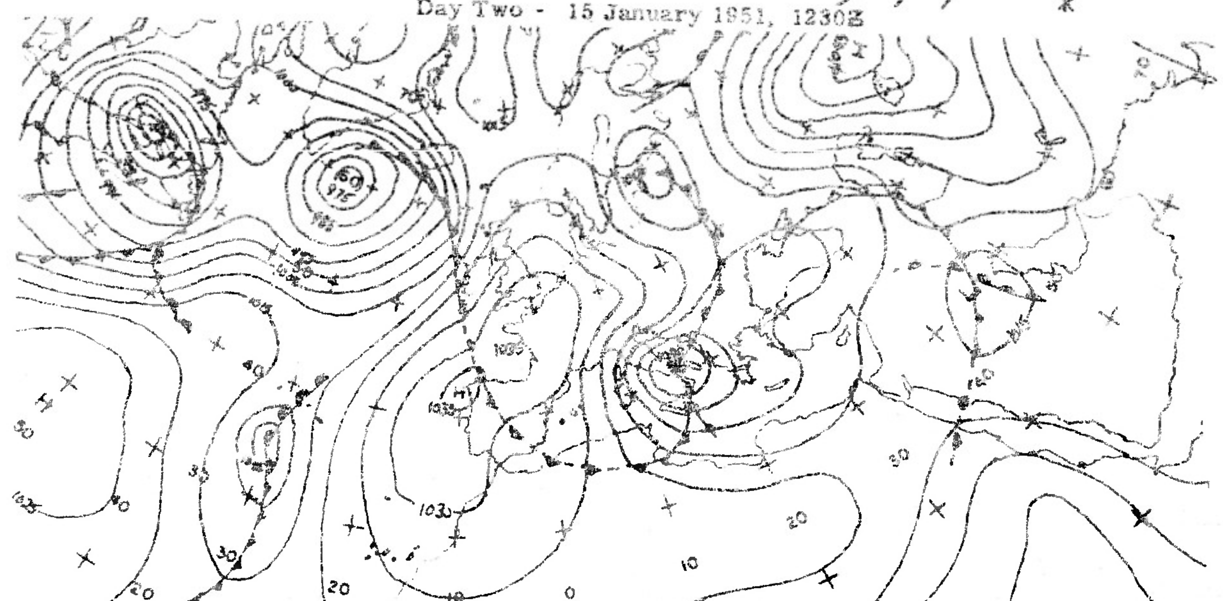
CASE NO. 7
Surface Charts



Case 7 Summary with Day One Prediction

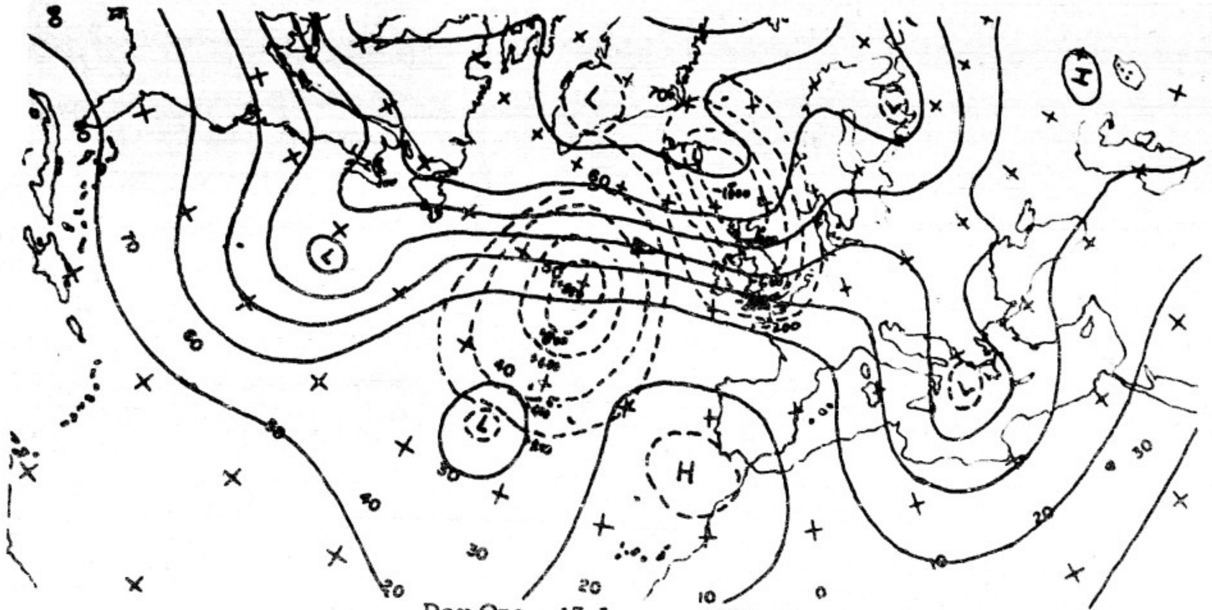


Day Two - 15 January 1951, 1230Z

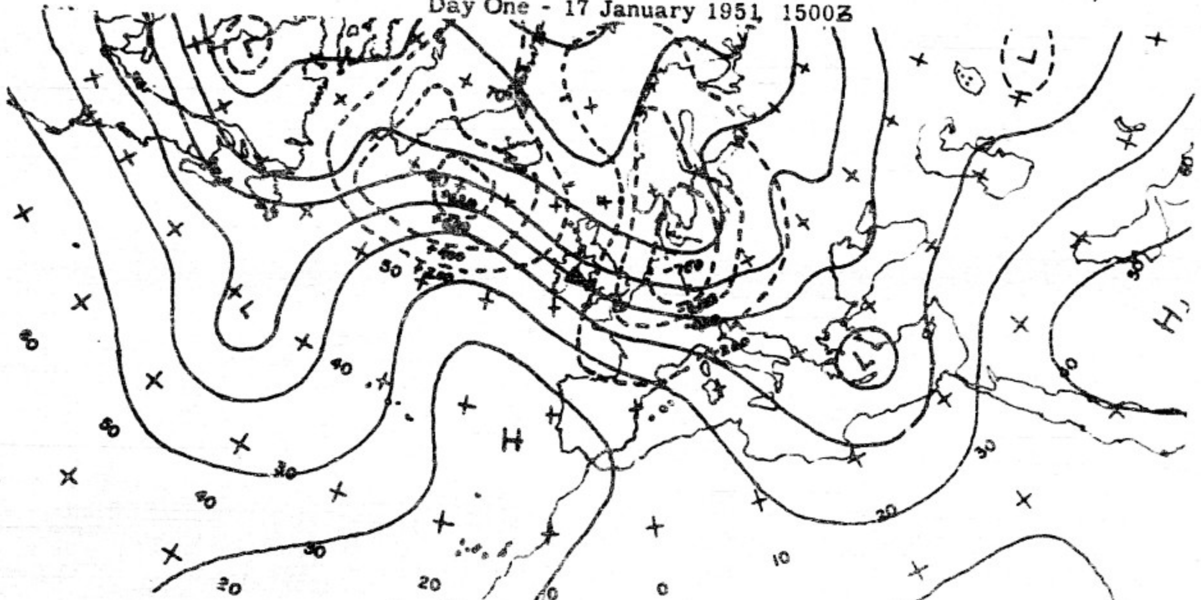


Day Three - 16 January 1951, 1230Z

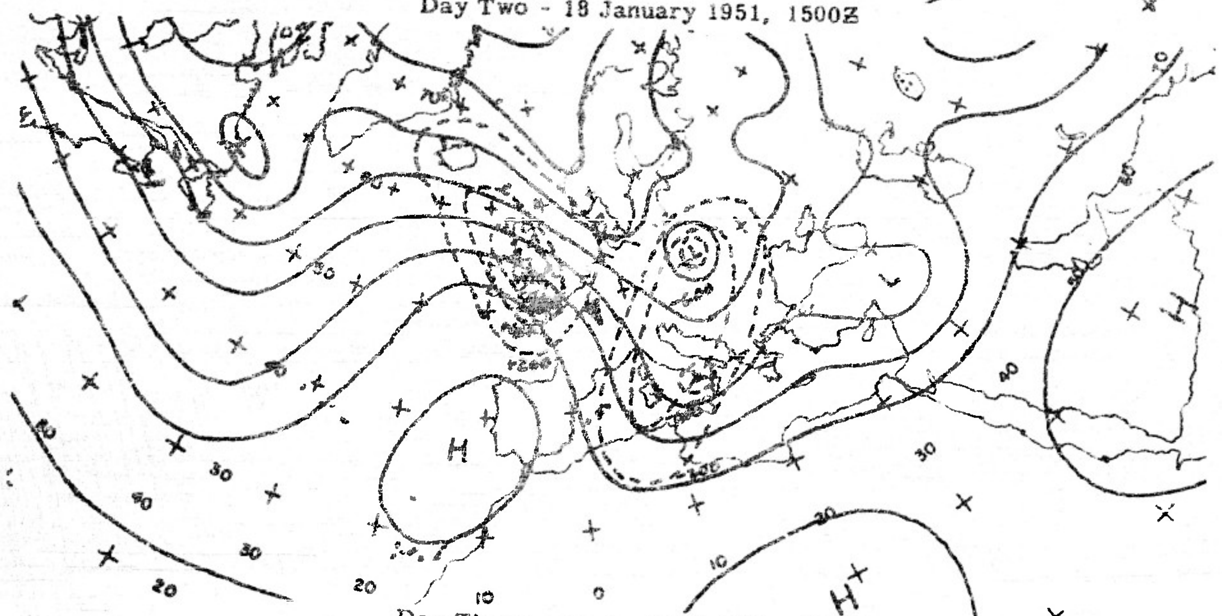
CASE NO. 8
500-Millibar Charts



Day One - 17 January 1951, 1500Z

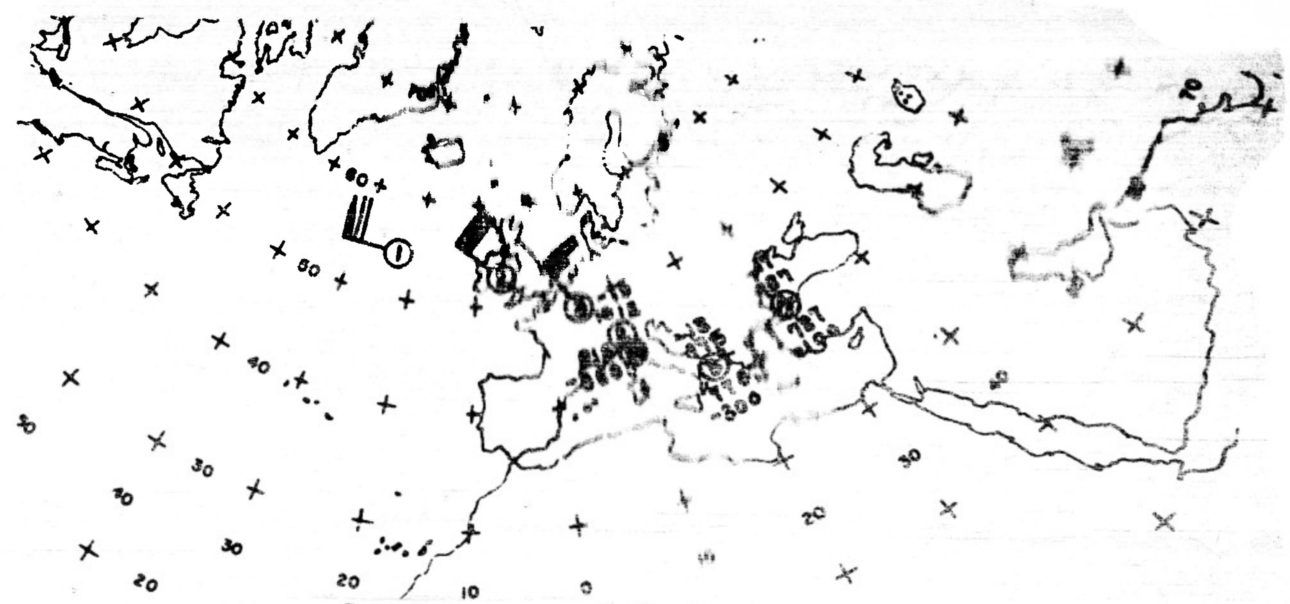


Day Two - 18 January 1951, 1500Z

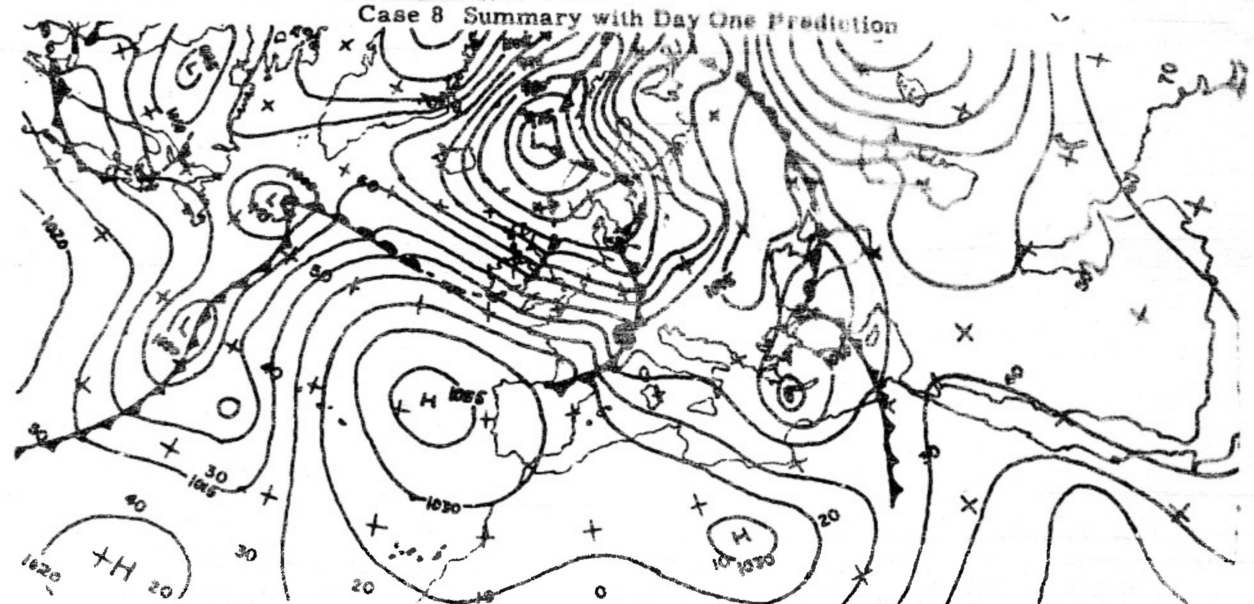


Day Three - 19 January 1951, 1500Z

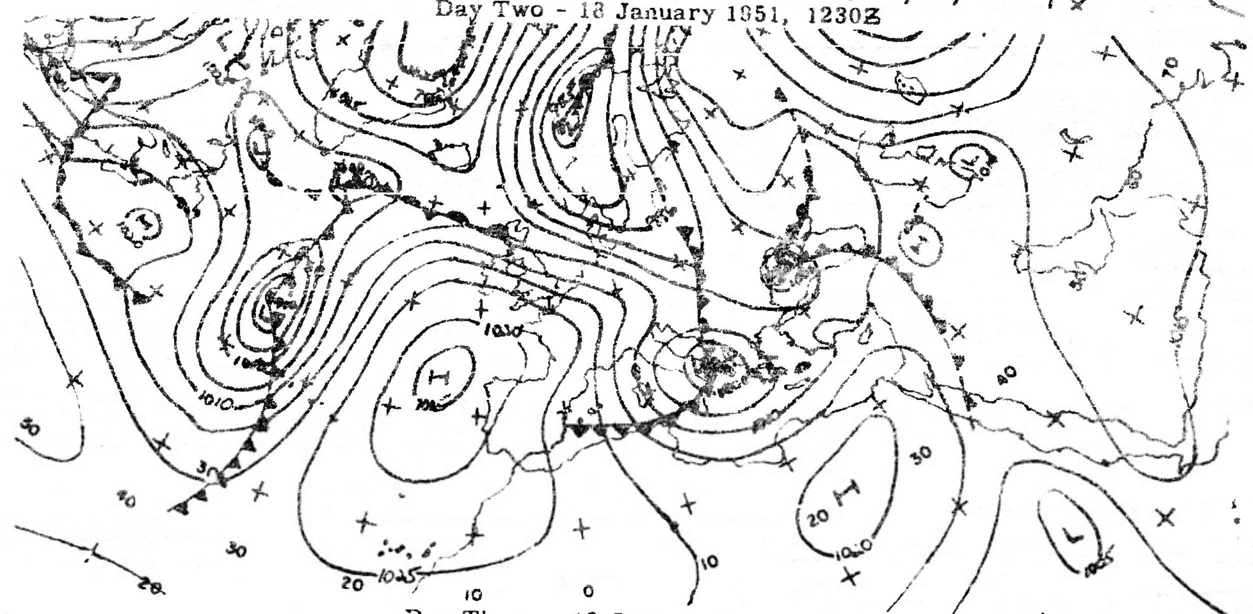
CASE NO. 8
Surface Charts



Case 8 Summary with Day One Prediction

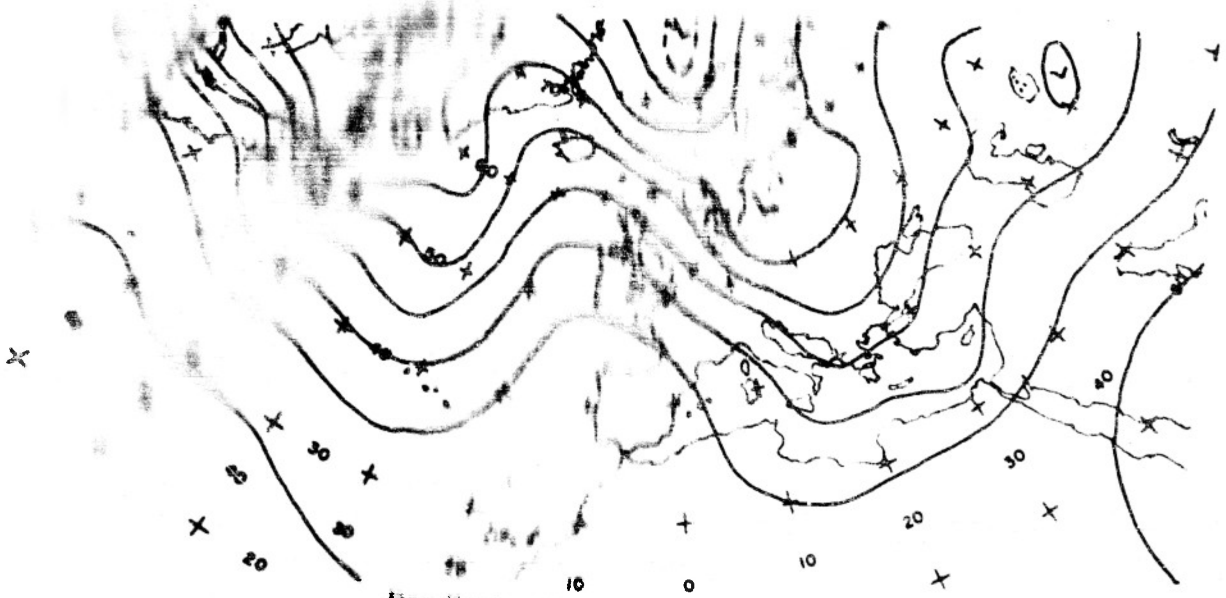


Day Two - 18 January 1951, 1230Z



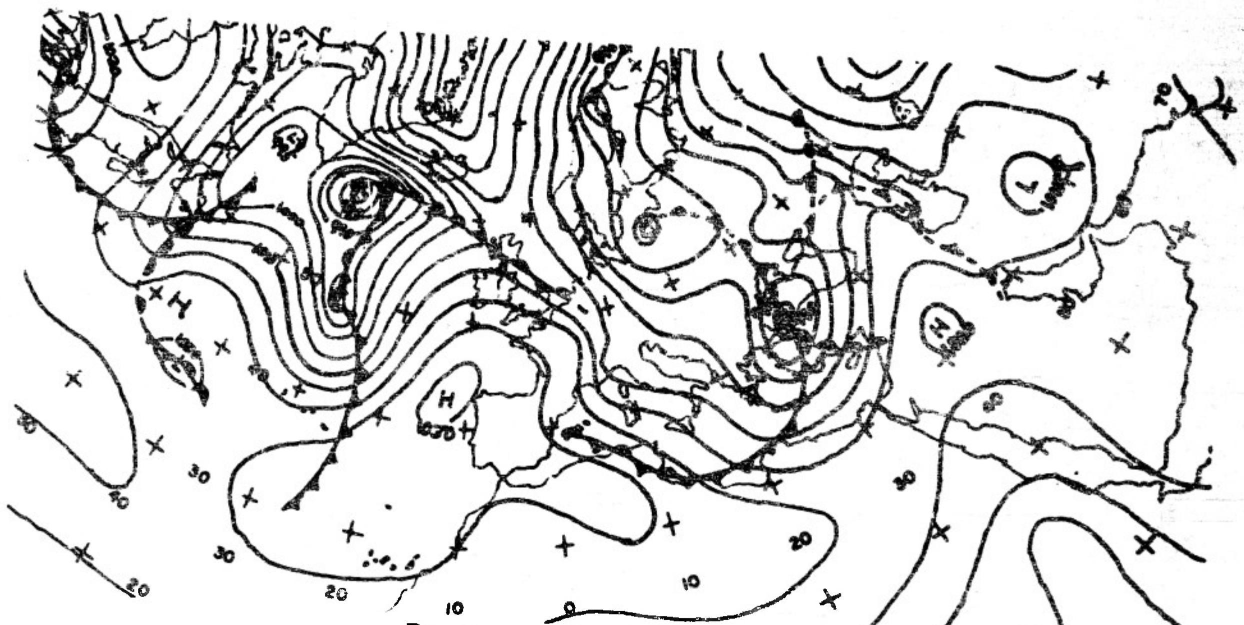
Day Three - 19 January 1951, 1230Z

CASE NO. 8
Millibar Chart



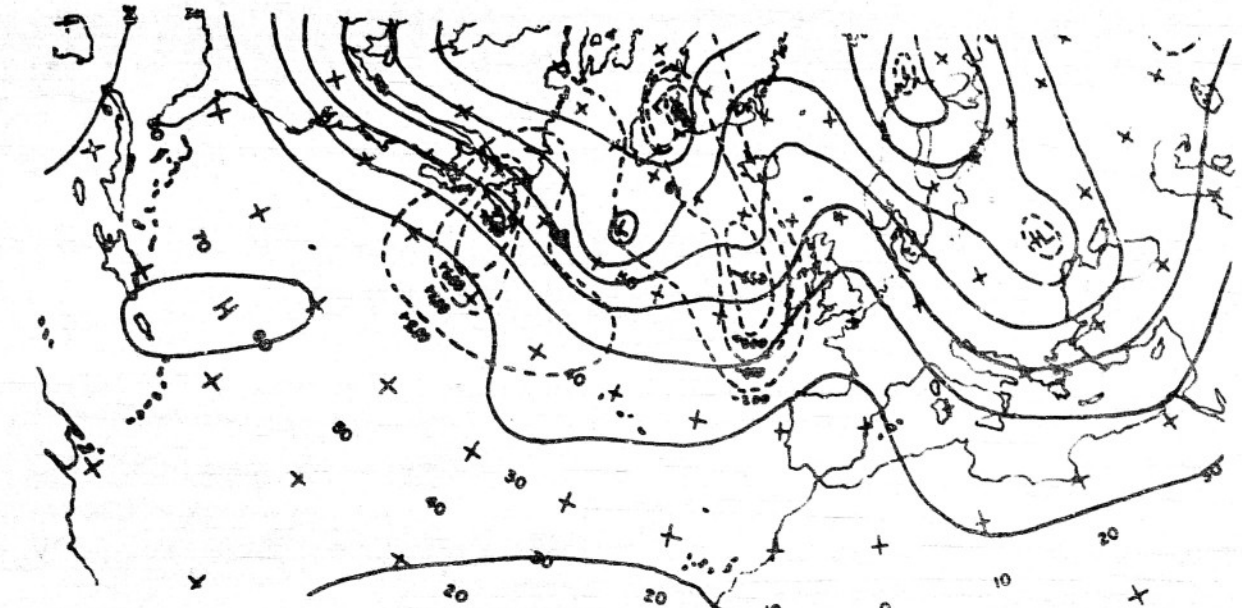
Day Four - 20 January 1951, 1500Z

CASE NO. 8
Surface Charts

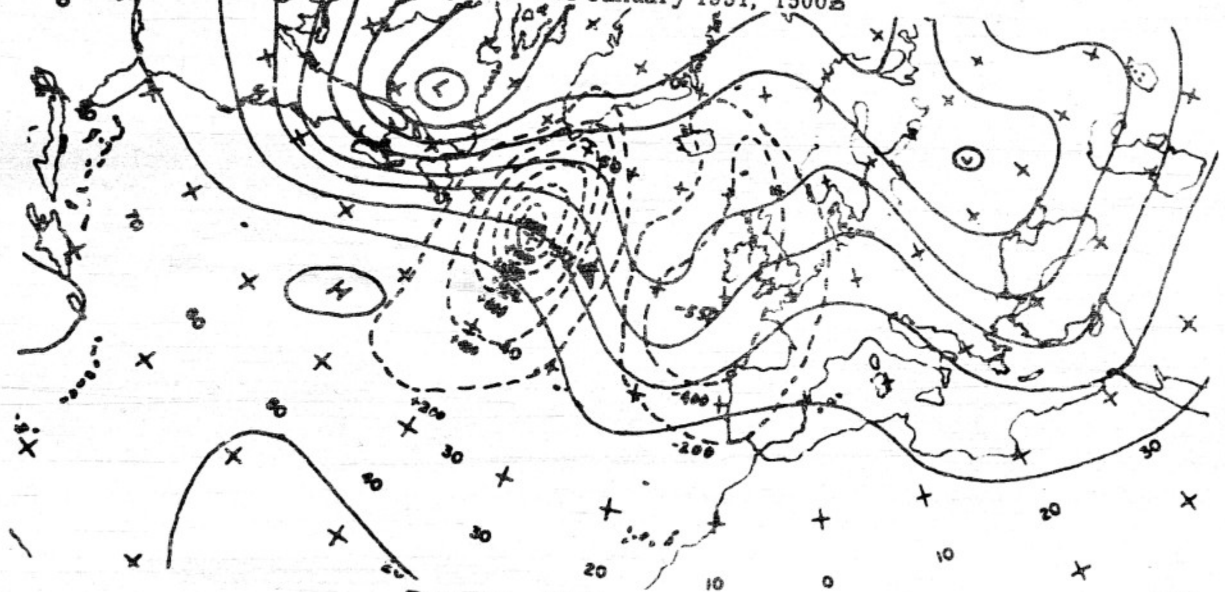


Day Four - 20 January 1951, 1230Z

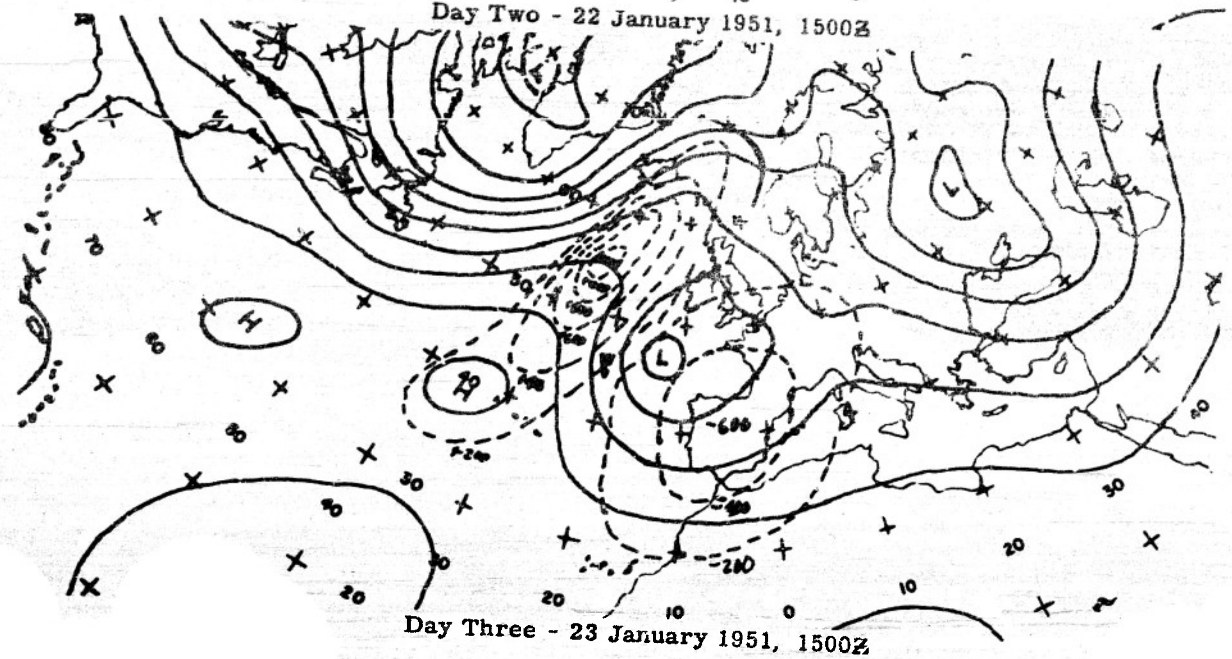
CASE NO. 9
500-Millibar Charts



Day One - 21 January 1951, 1500Z

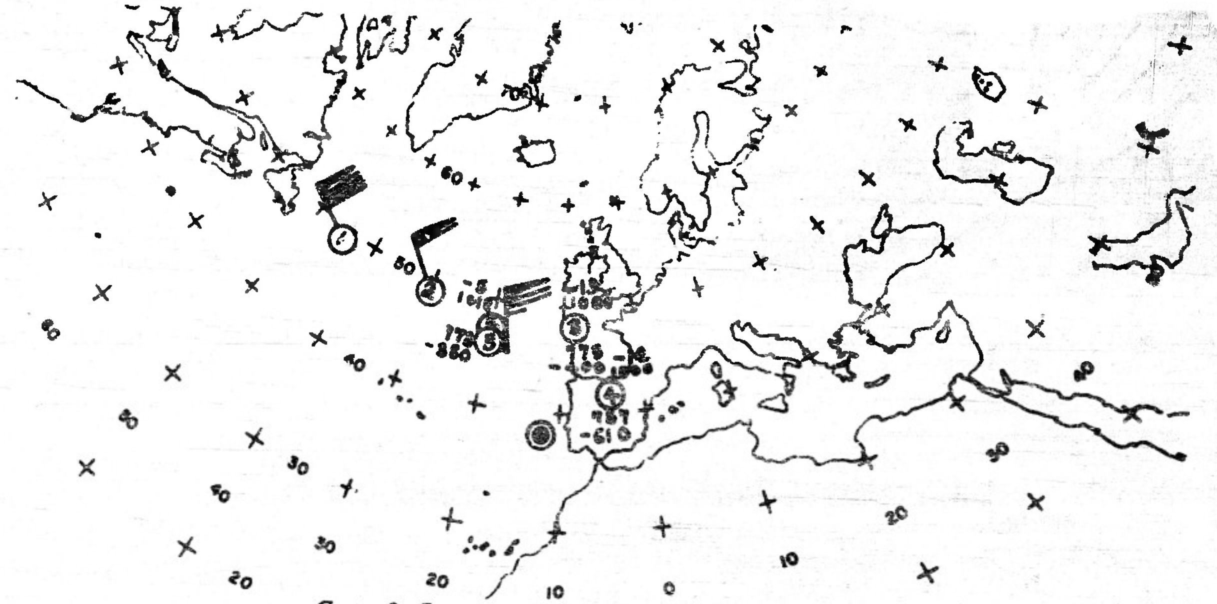


Day Two - 22 January 1951, 1500Z

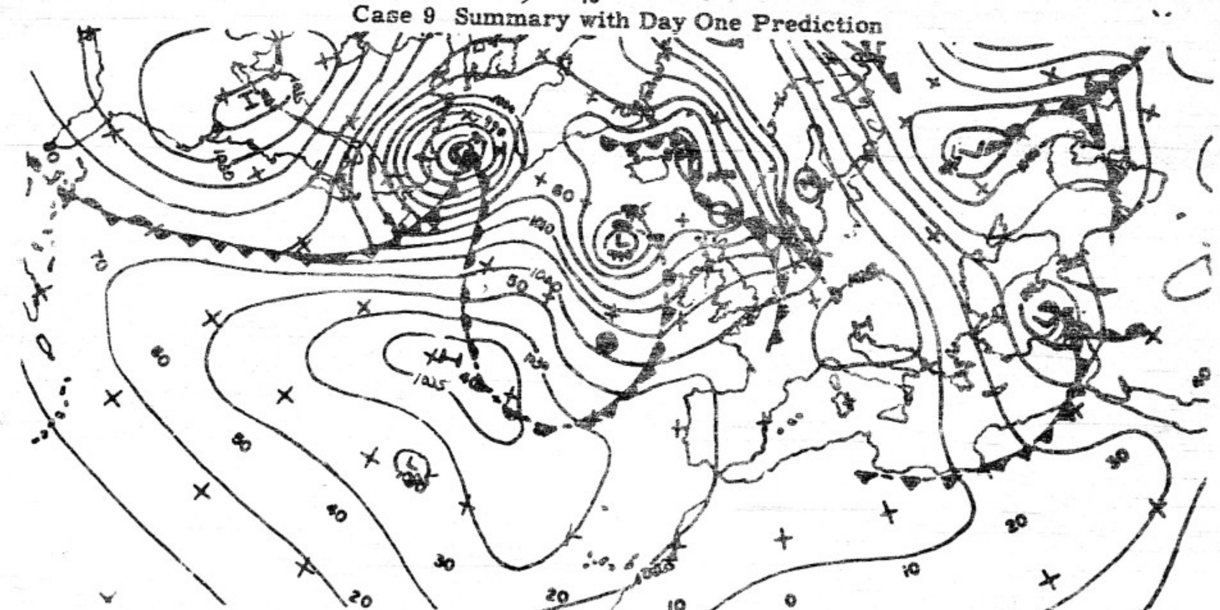


Day Three - 23 January 1951, 1500Z

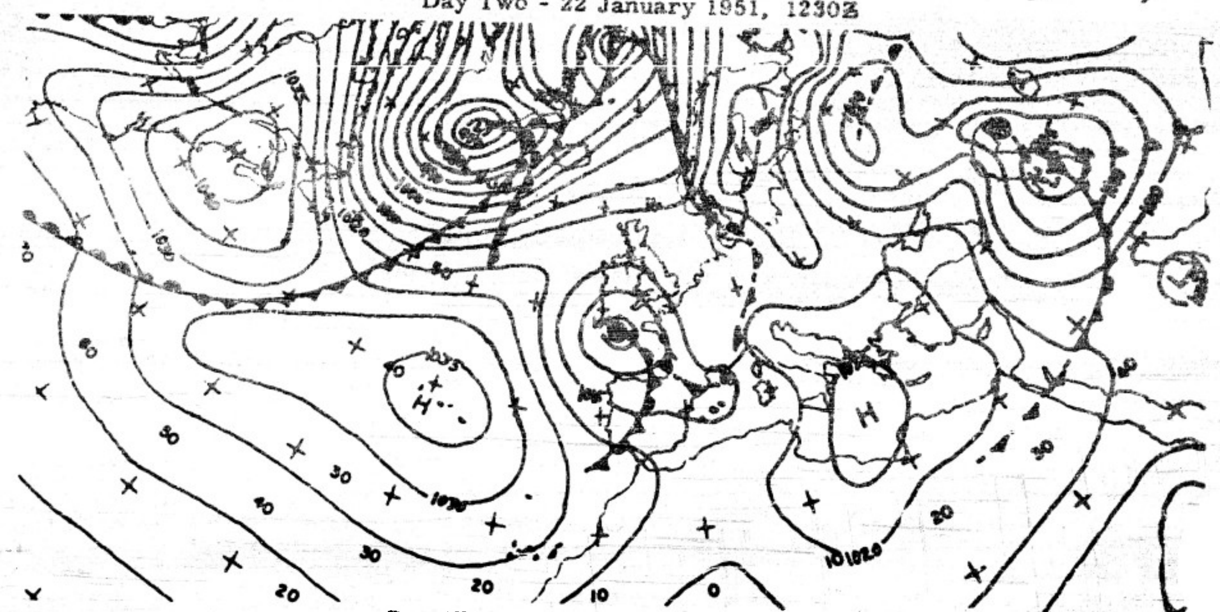
CASE NO. 9
Surface Charts



Case 9 Summary with Day One Prediction

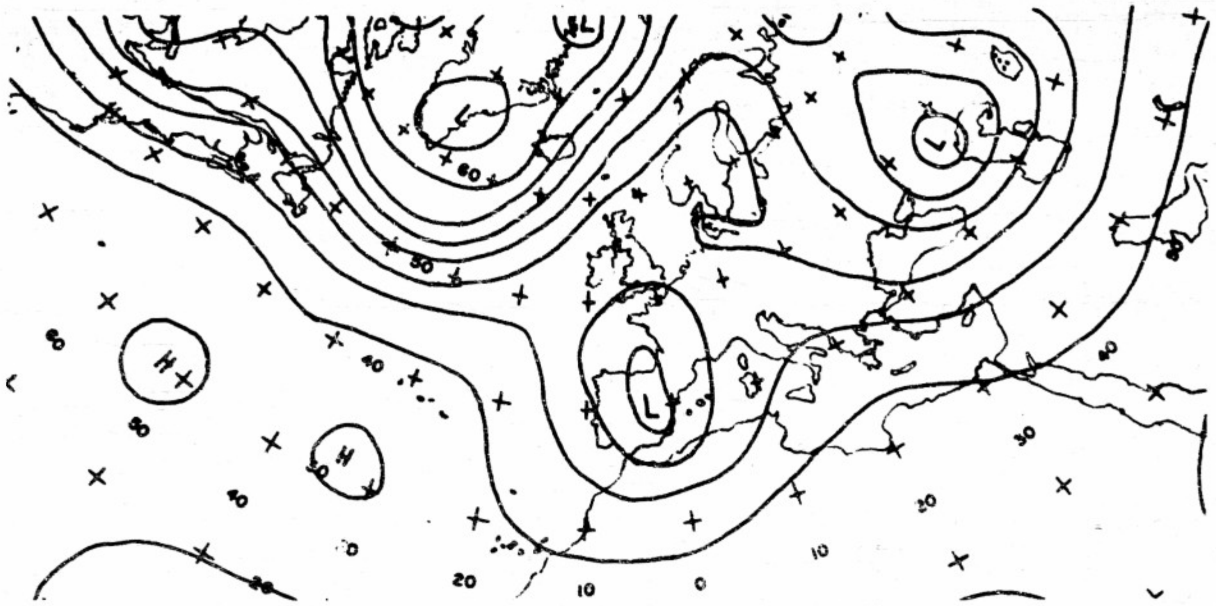


Day Two - 22 January 1951, 1230Z



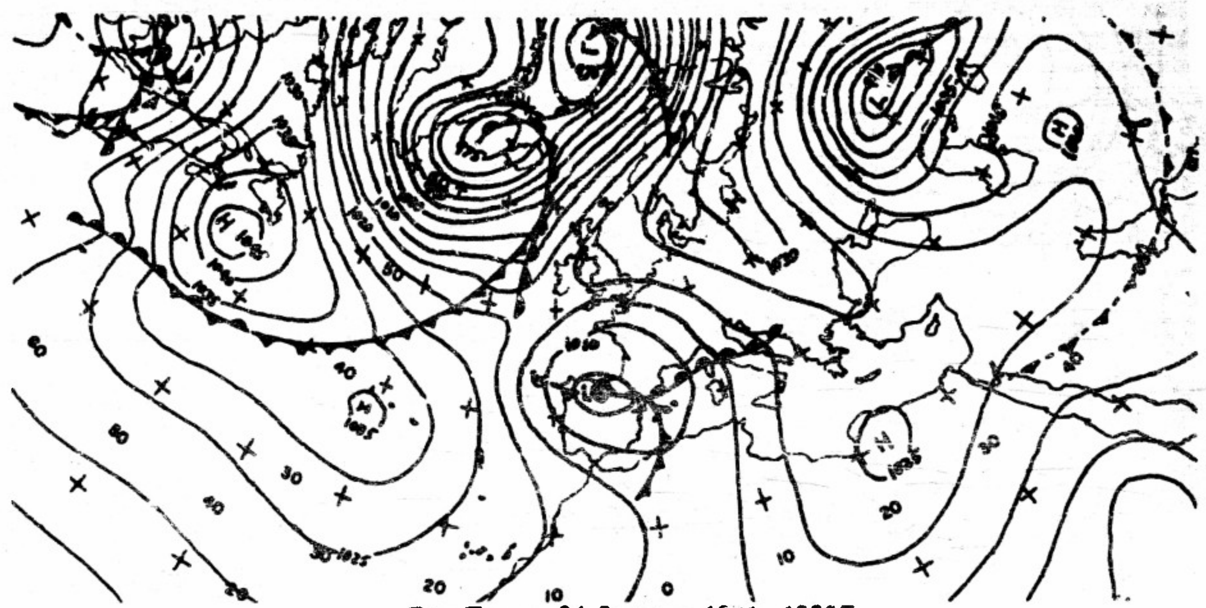
Day Three - 23 January 1951, 1230Z

CASE NO. 9
500-Millibar Charts



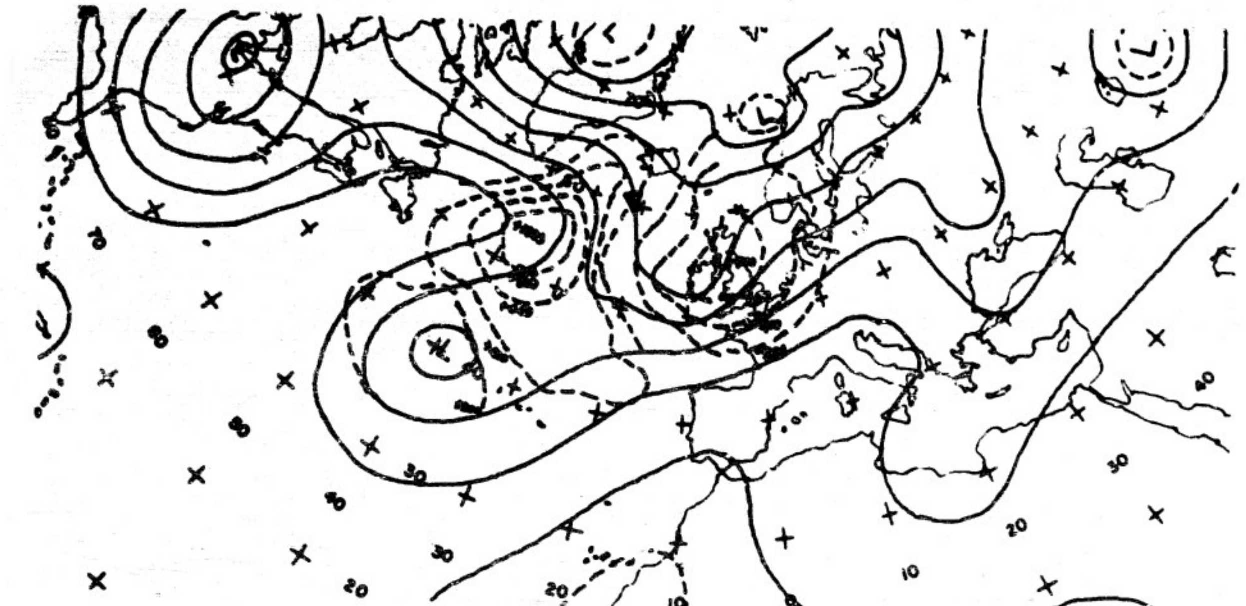
Day Four - 24 January 1951, 1500Z

CASE NO. 9
Surface Charts

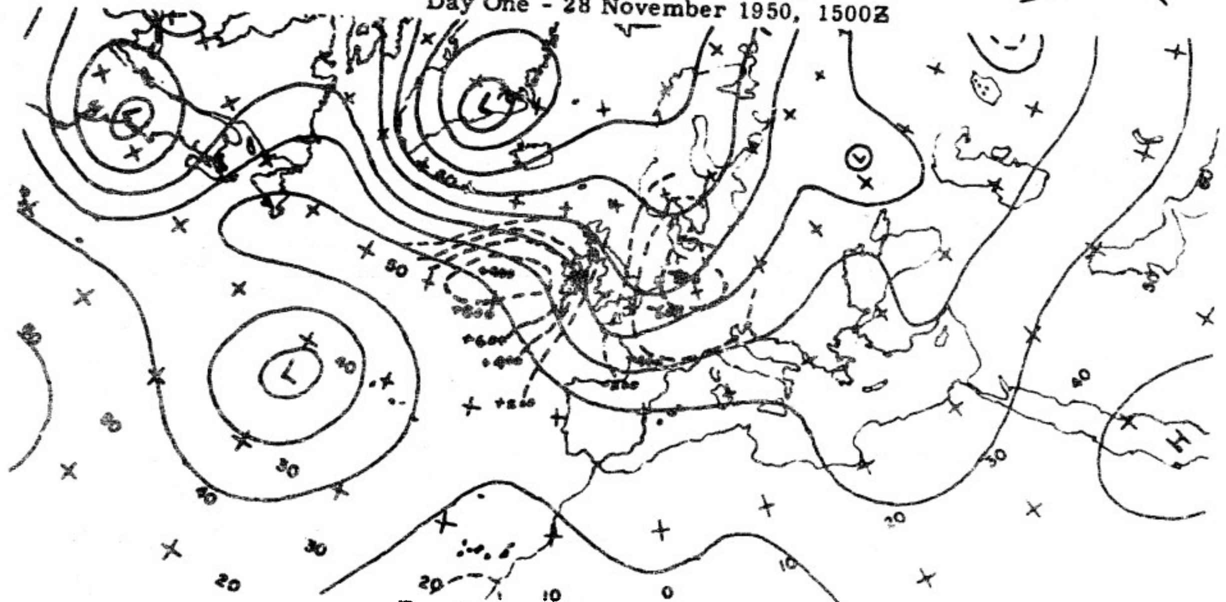


Day Four - 24 January 1951, 1230Z

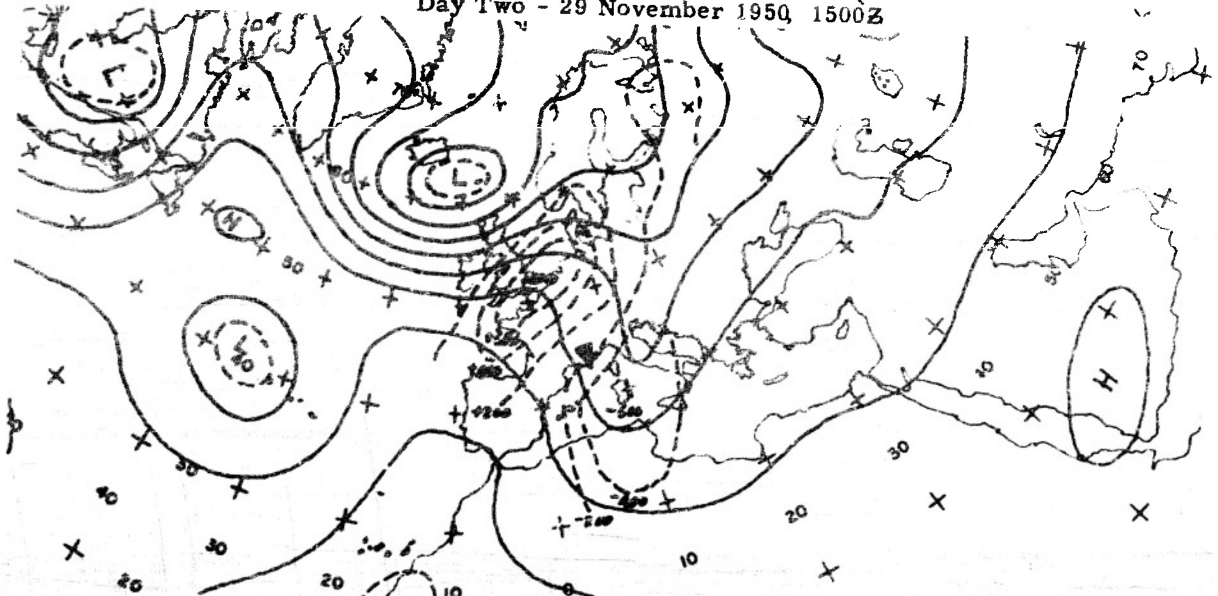
CASE NO. 10
500-Millibar Charts



Day One - 28 November 1950, 1500Z



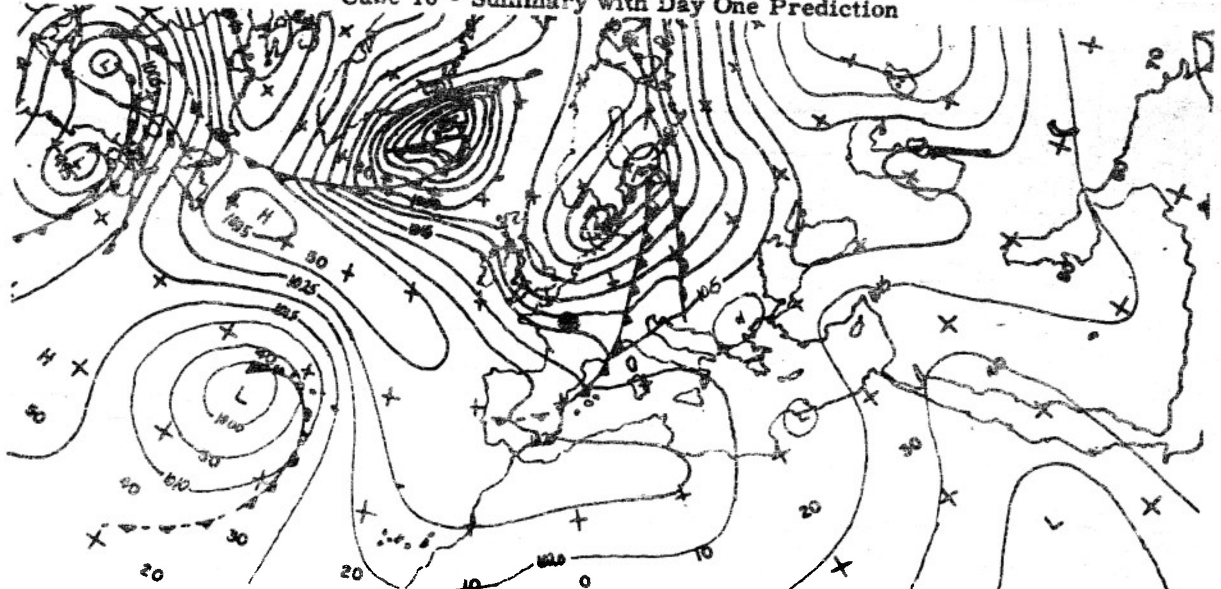
Day Two - 29 November 1950, 1500Z



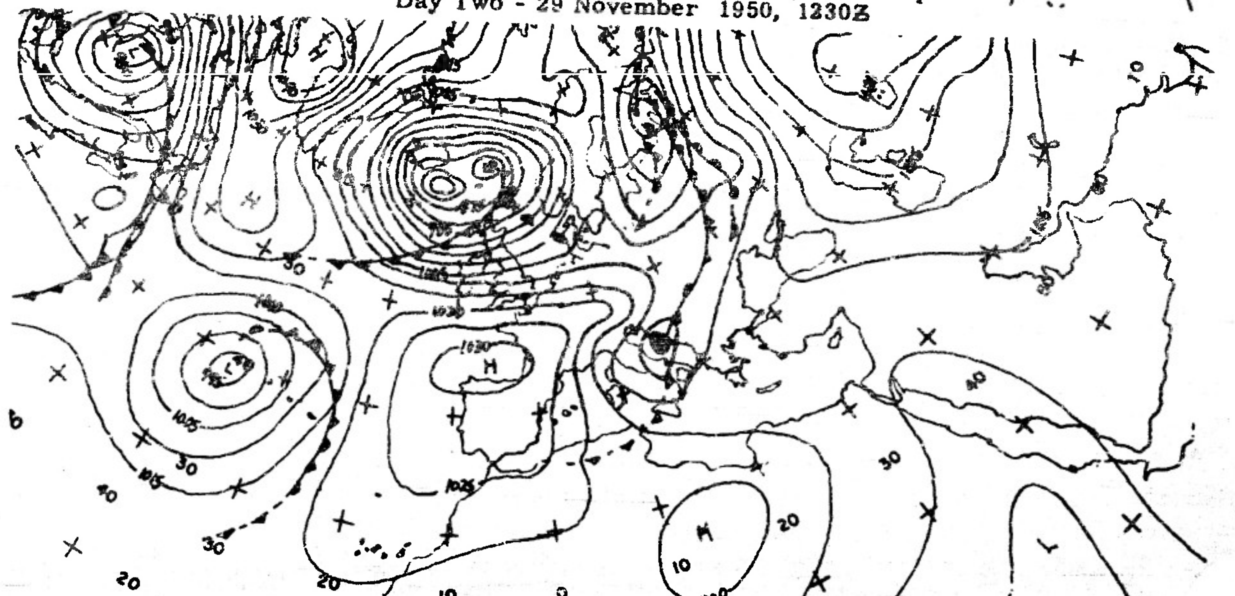
Day Three - 30 November 1950, 1500Z

CASE NO. 10
Surface Charts

Case 10 - Summary with Day One Prediction

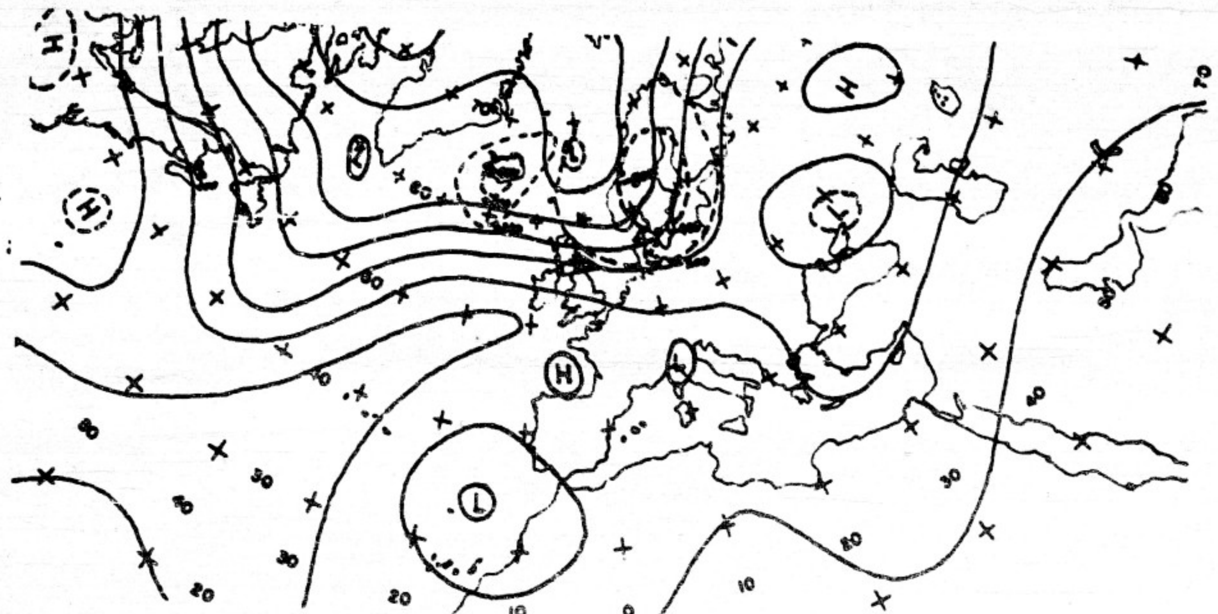


Day Two - 29 November 1950, 1230Z

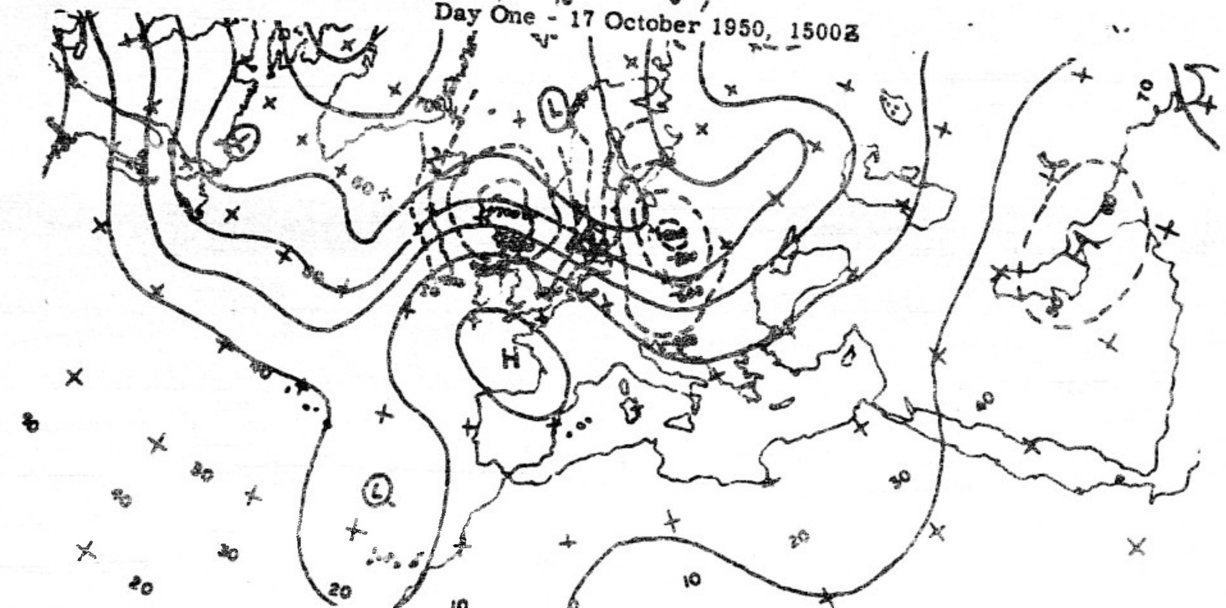


Day Three - 30 November 1950, 1230Z

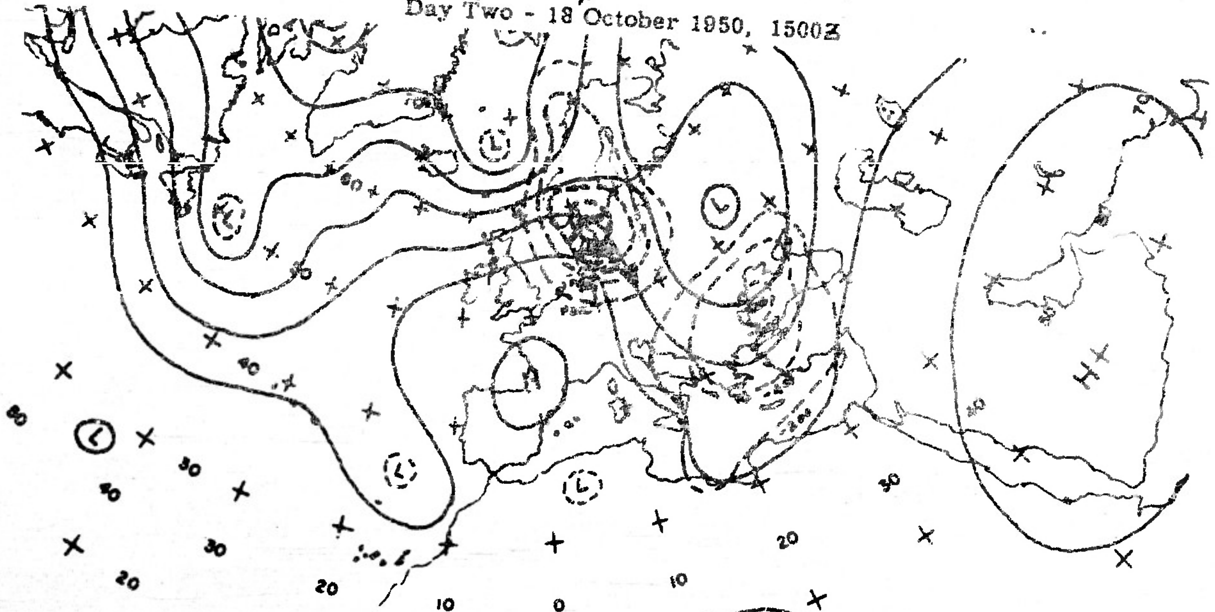
CASE NO. 11
500-Millibar Charts



Day One - 17 October 1950, 1500Z



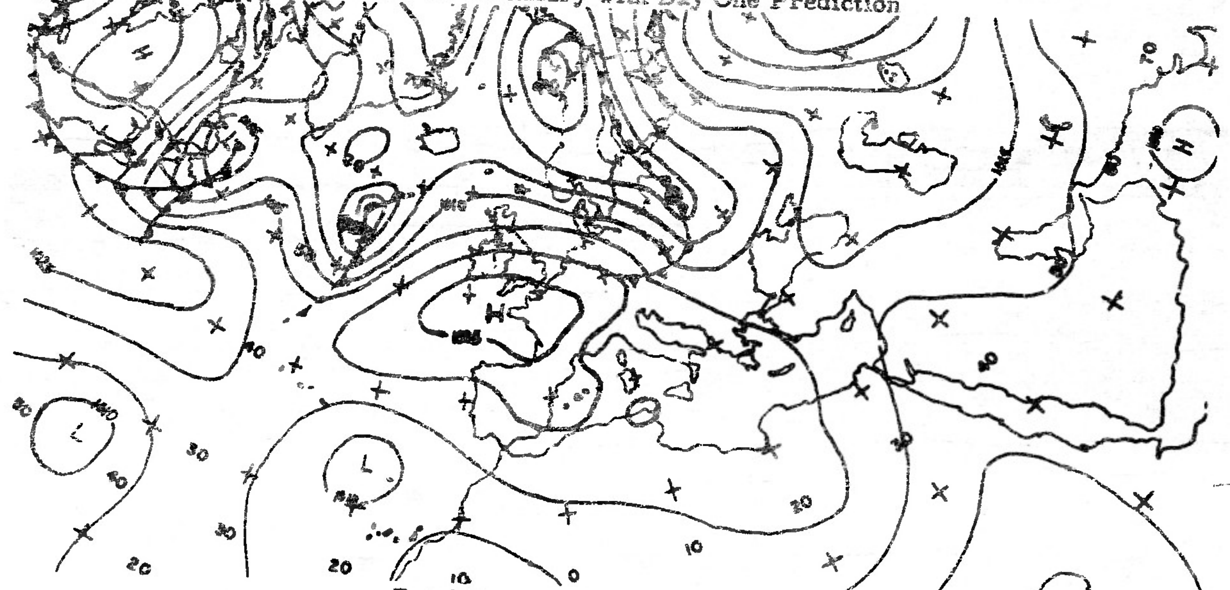
Day Two - 18 October 1950, 1500Z



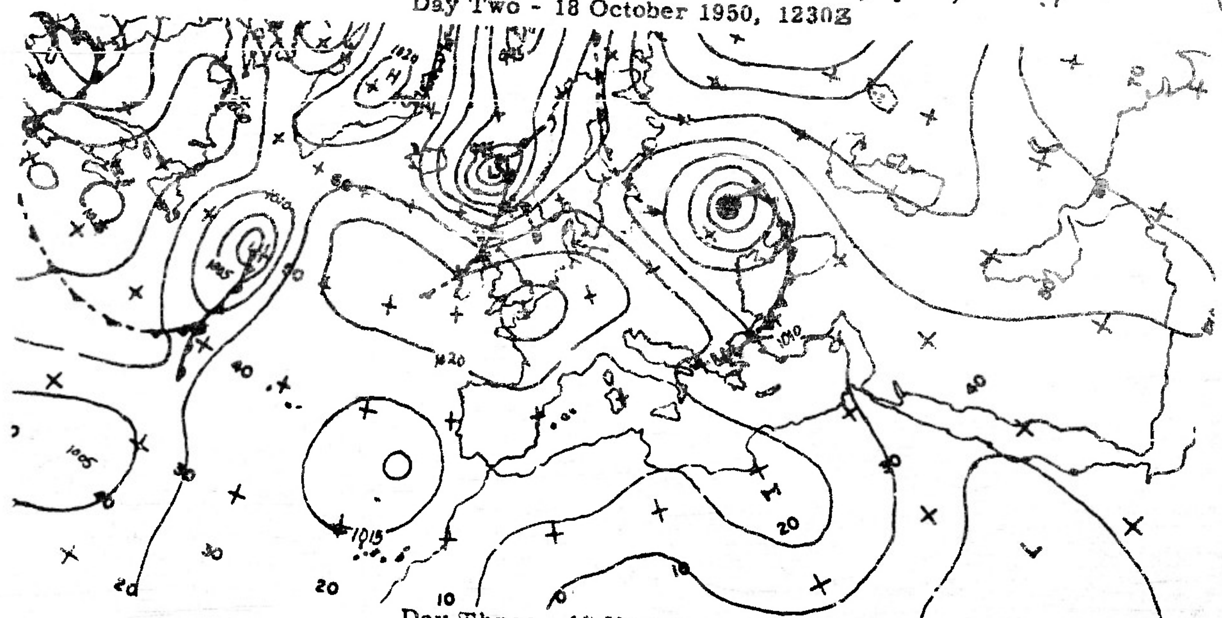
Day Three - 19 October 1950, 1500Z

CASE NO. 11
Surface Charts

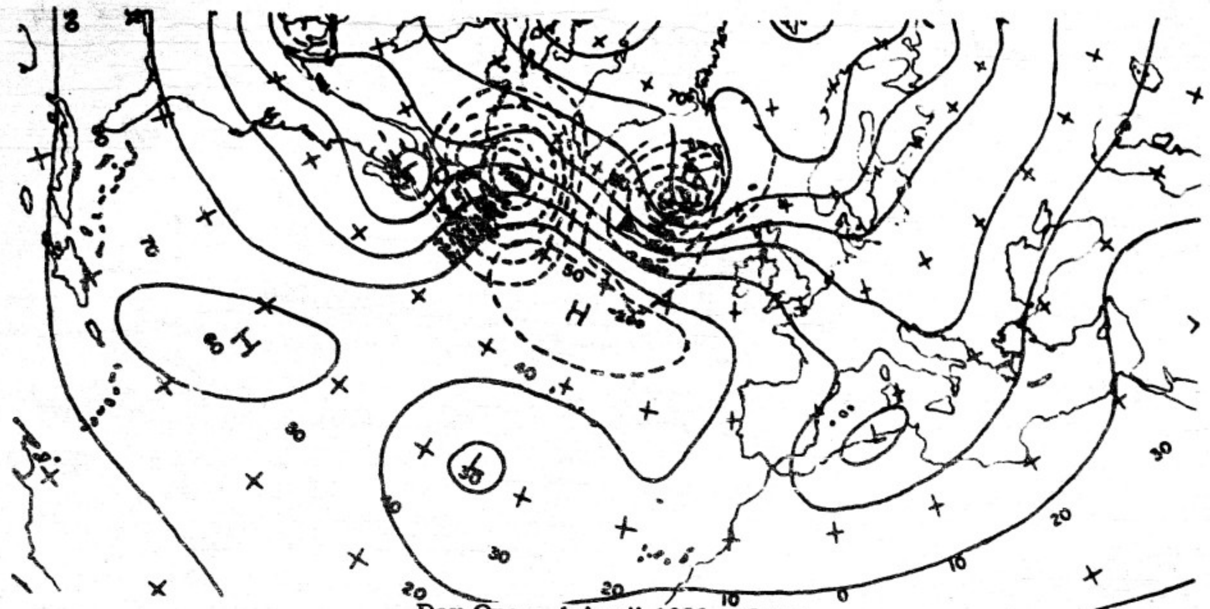
Case 11 Summary with Day One Prediction



Day Two - 18 October 1950, 1230Z

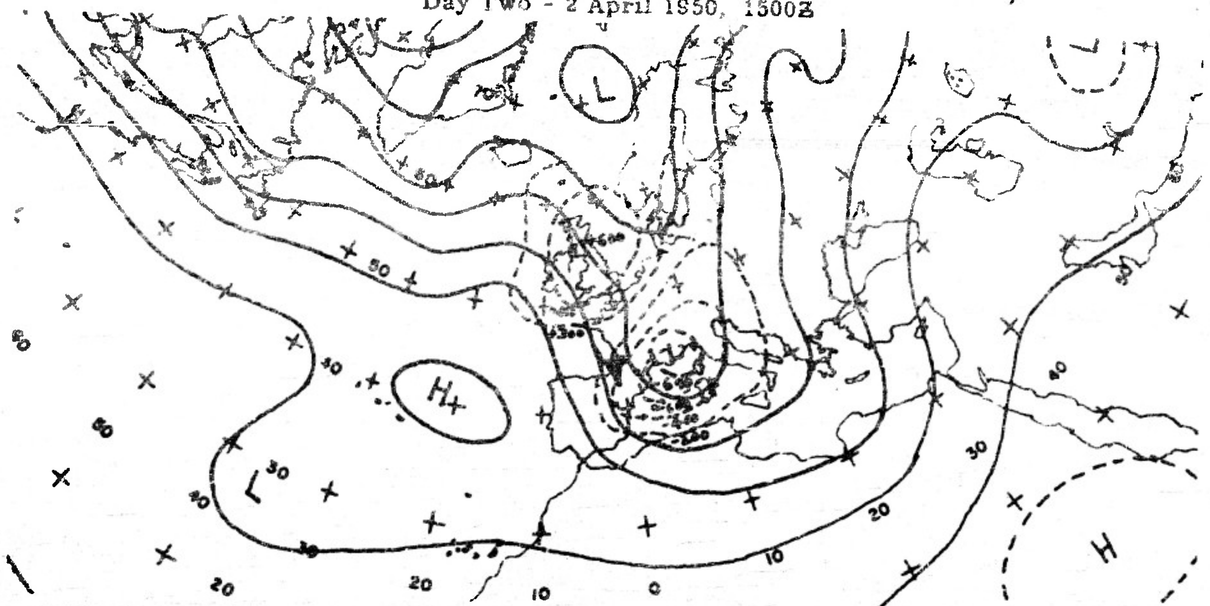


Day Three - 19 November 1950, 1230Z



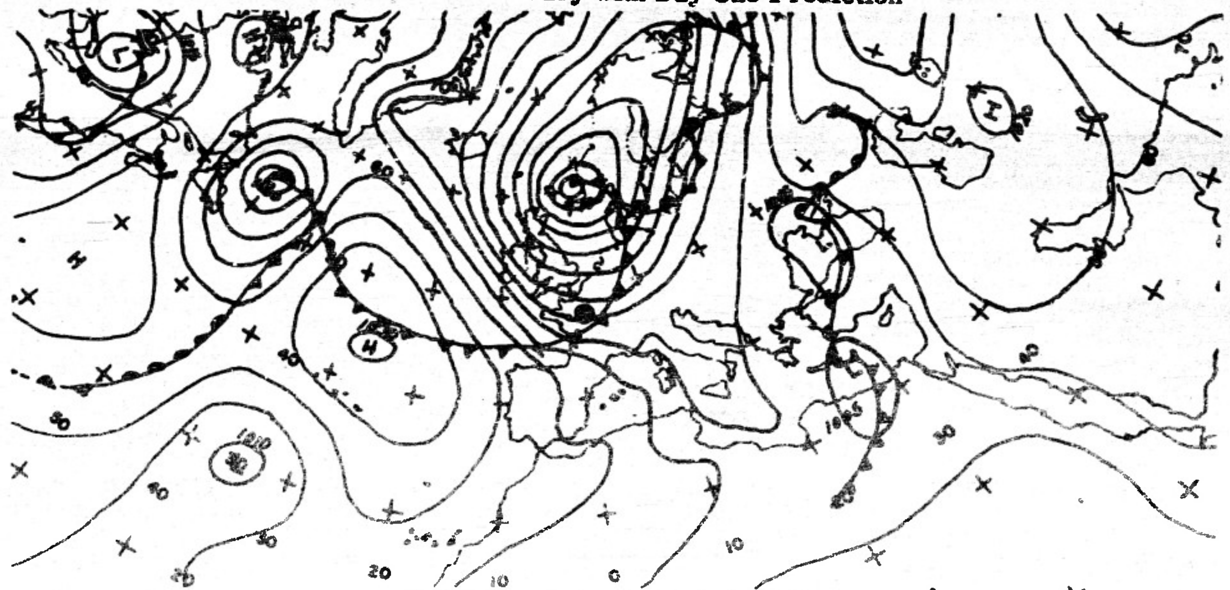
Day One - 1 April 1950, 1500Z

Day Two - 2 April 1950, 1500Z

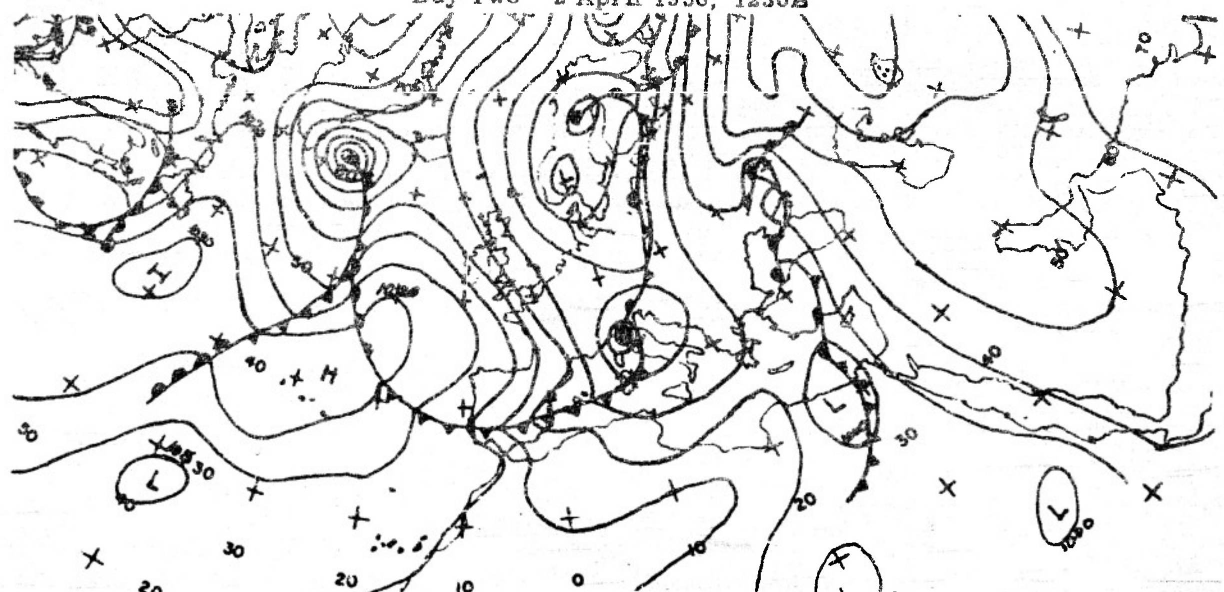


Day Three - 3 April 1950, 1500Z

Case 12 - Summary with Day One Prediction

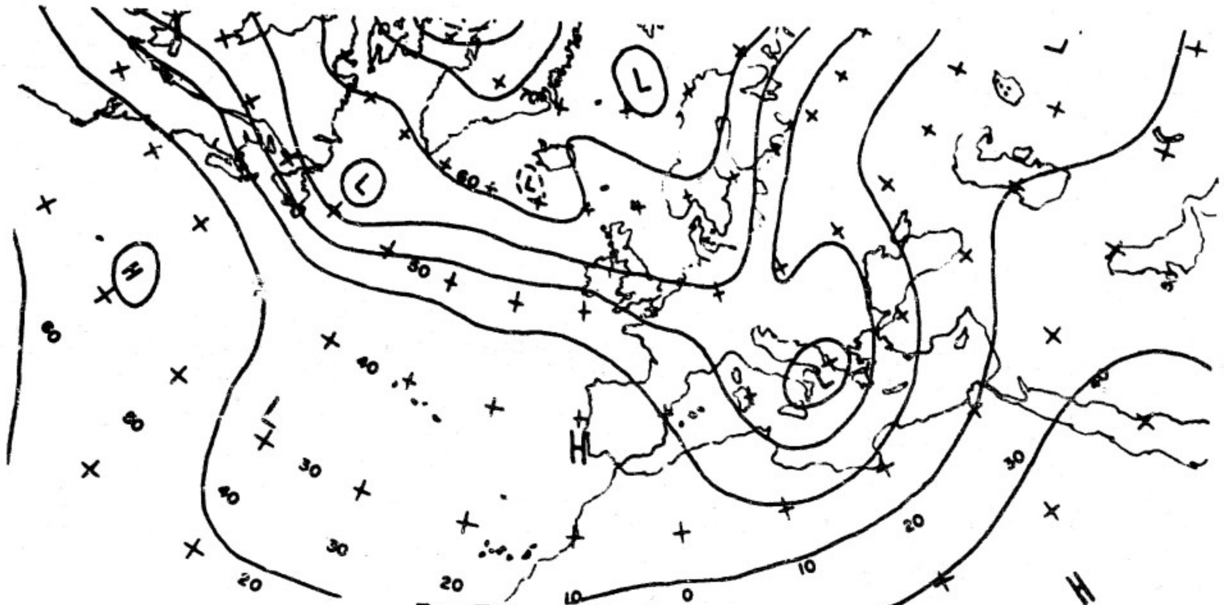


Day Two - 2 April 1950, 1230Z



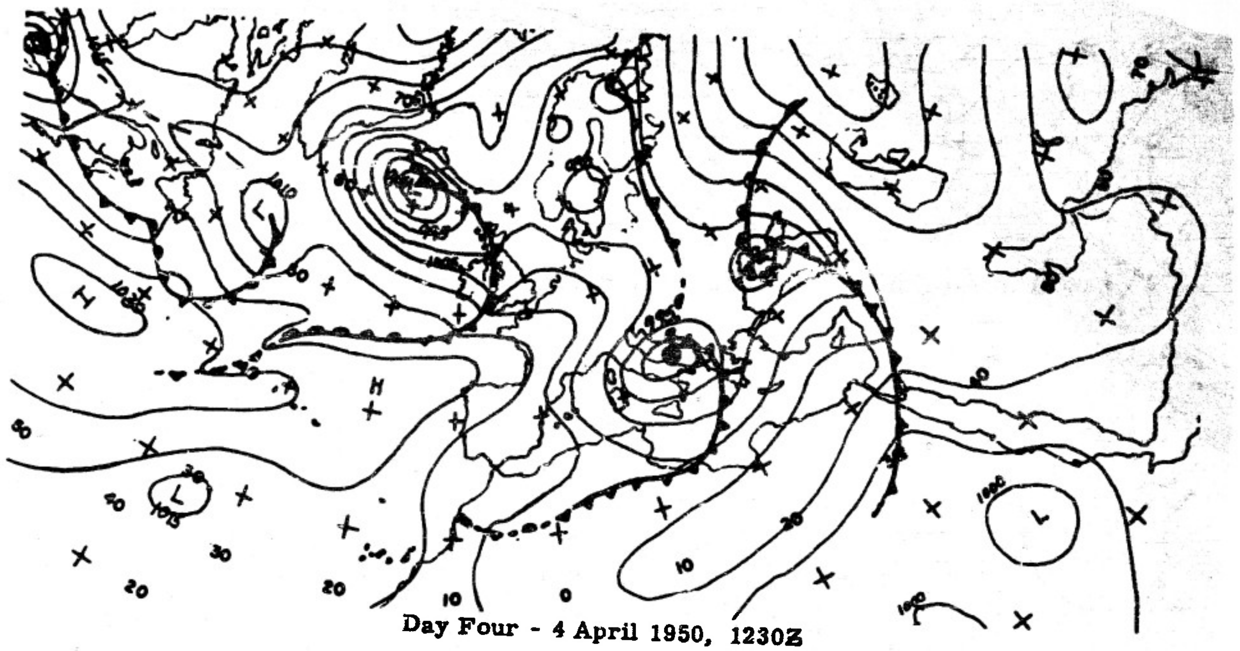
Day Three - 3 April 1950, 1230Z

CASE NO. 12
500-Millibar Charts



Day Four - 4 April 1950, 1500Z

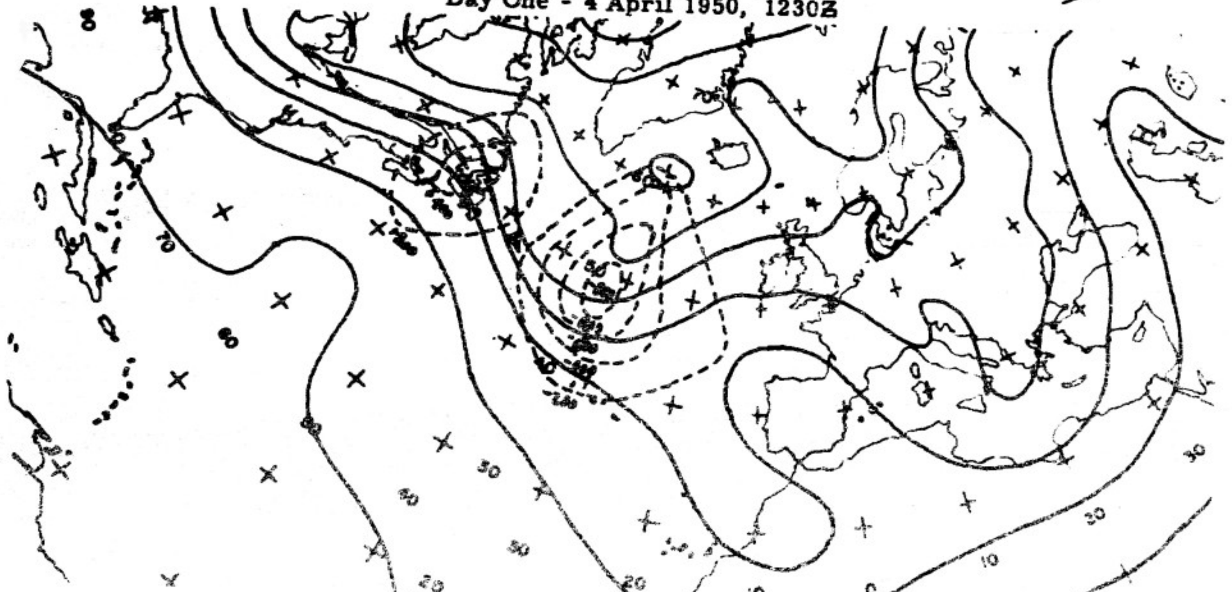
CASE NO. 12
Surface Charts



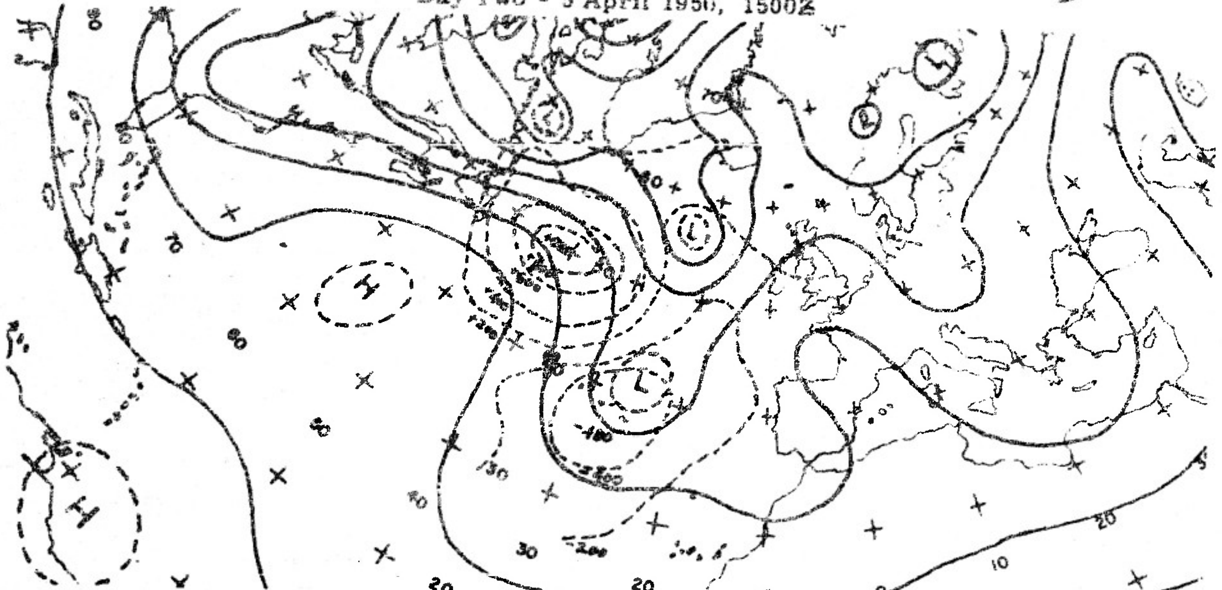
Day Four - 4 April 1950, 1230Z

CASE NO. 13
500-Millibar Charts

Day One - 4 April 1950, 1230Z

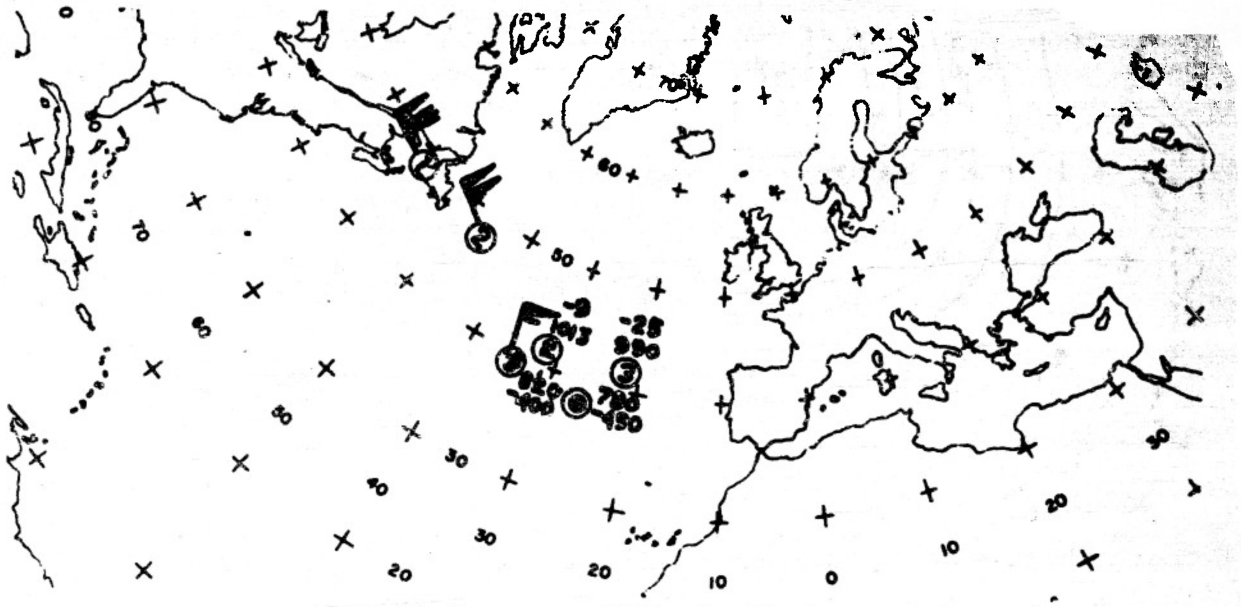


Day Two - 5 April 1950, 1500Z

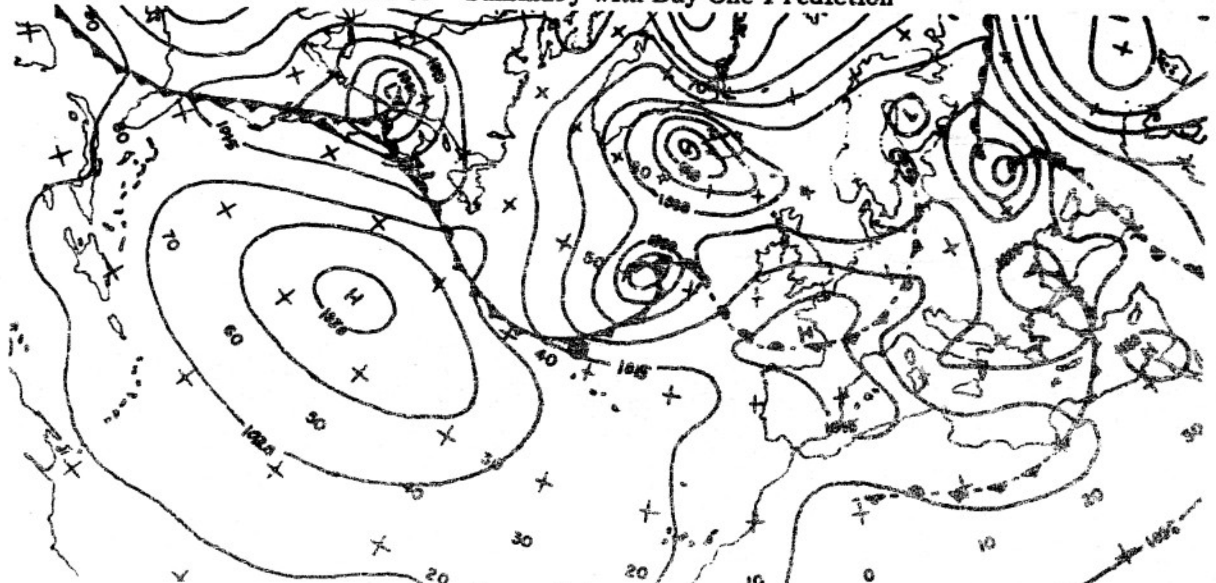


Day Three - 6 April 1950, 1500Z

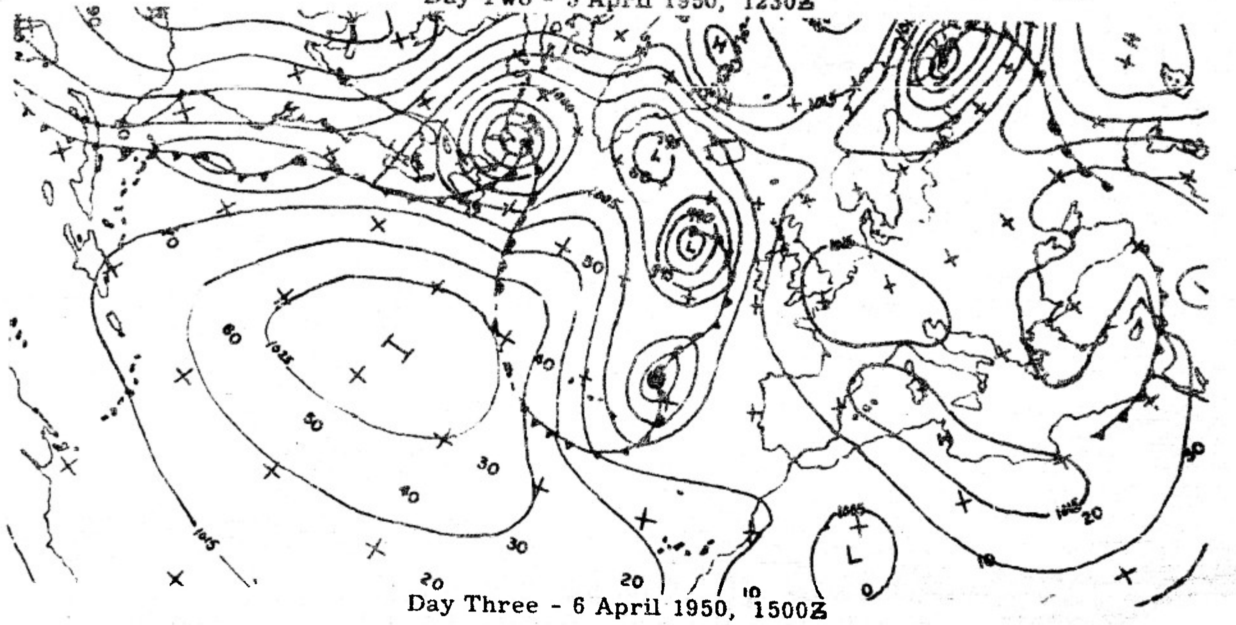
CASE NO. 13
Surface Charts



Case 13 Summary with Day One Prediction

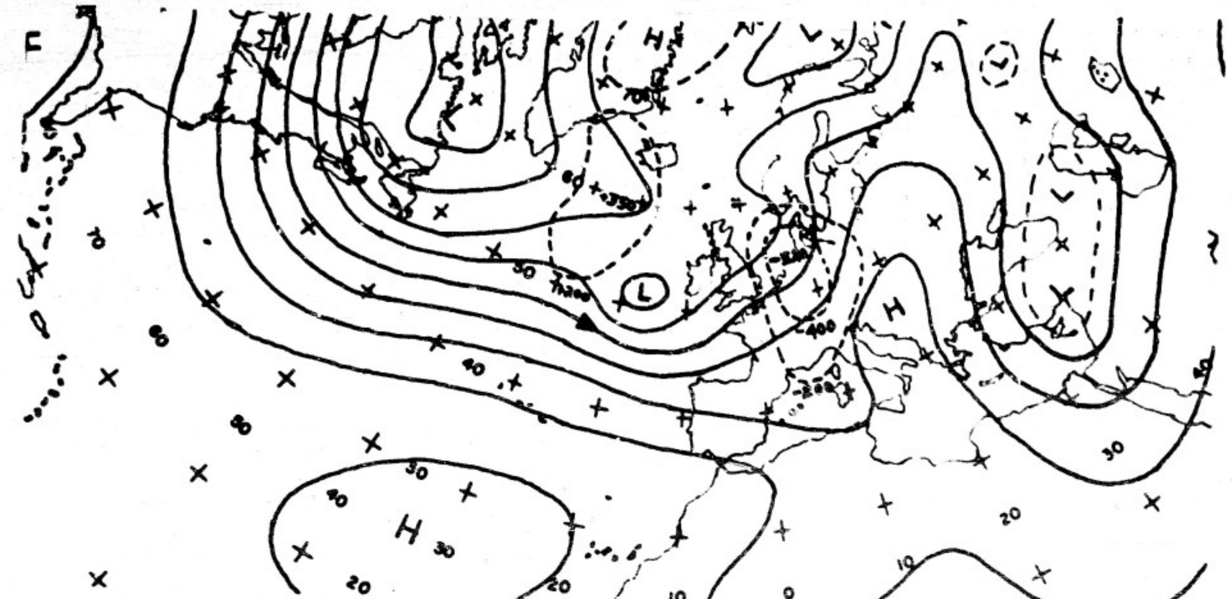


Day Two - 5 April 1950, 1230Z

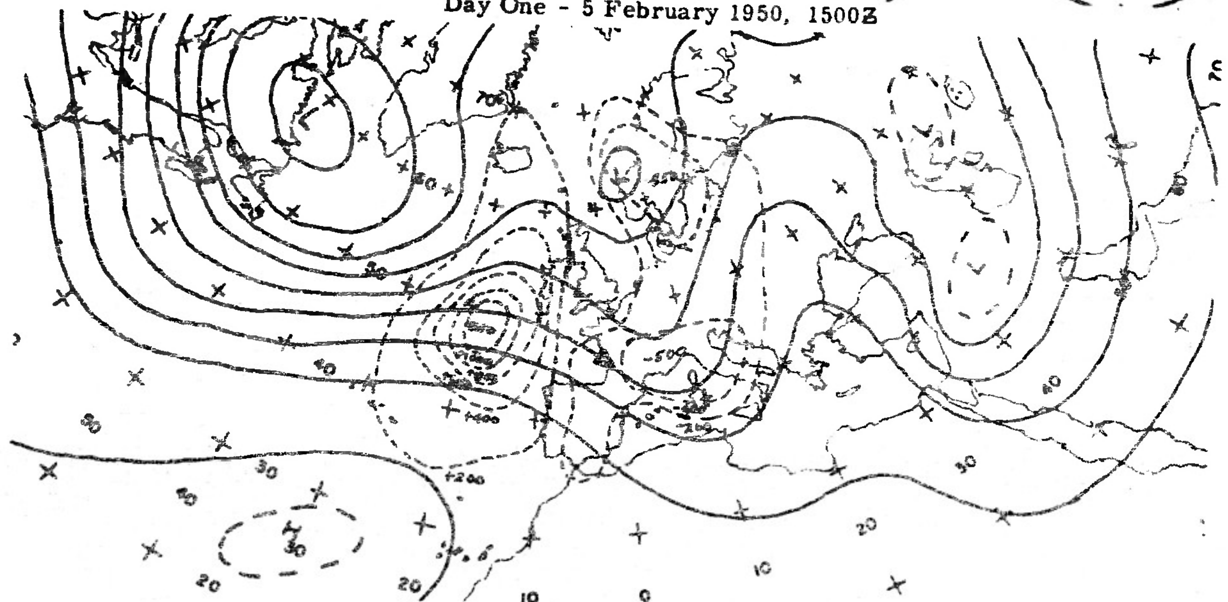


Day Three - 6 April 1950, 1500Z

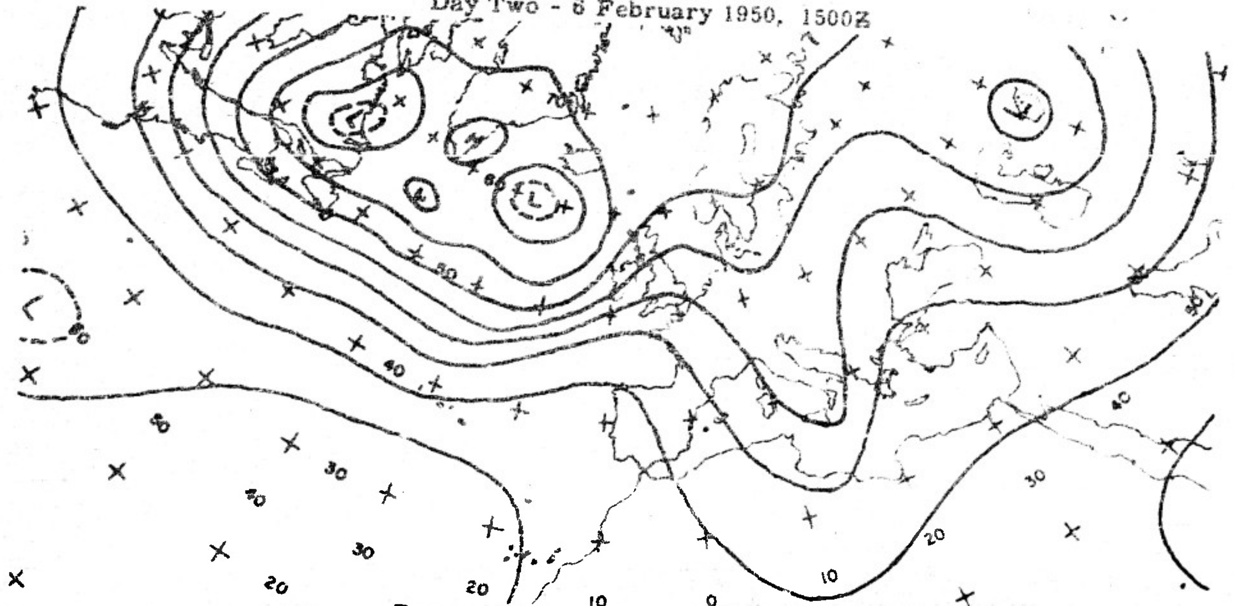
CASE NO. 14
500-Millibar Charts



Day One - 5 February 1950, 1500Z



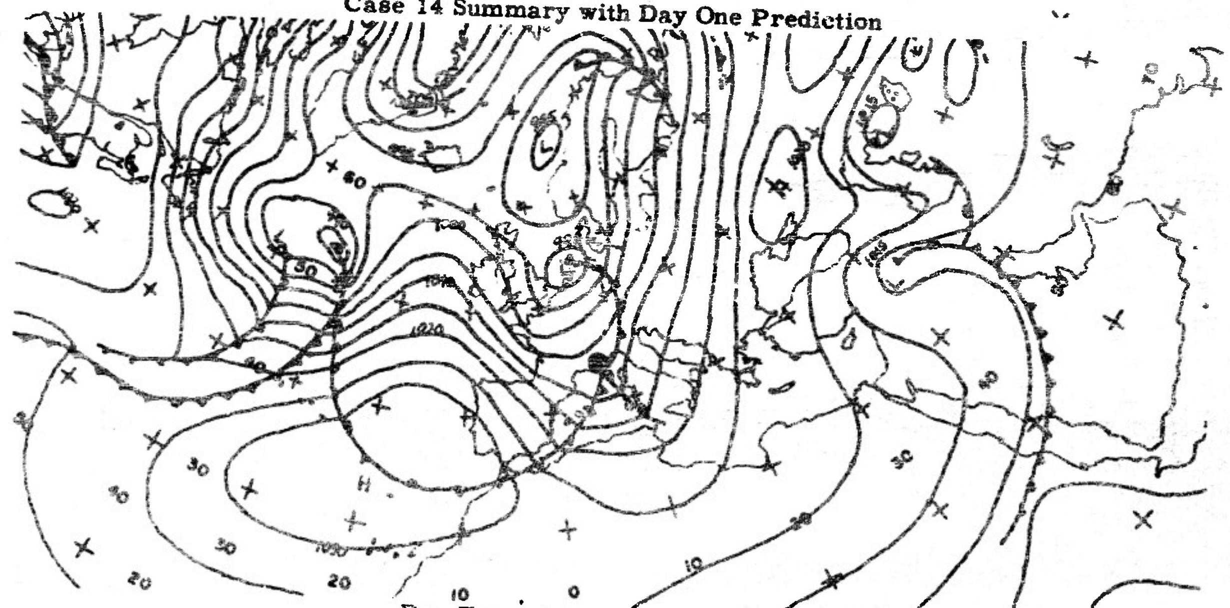
Day Two - 6 February 1950, 1500Z



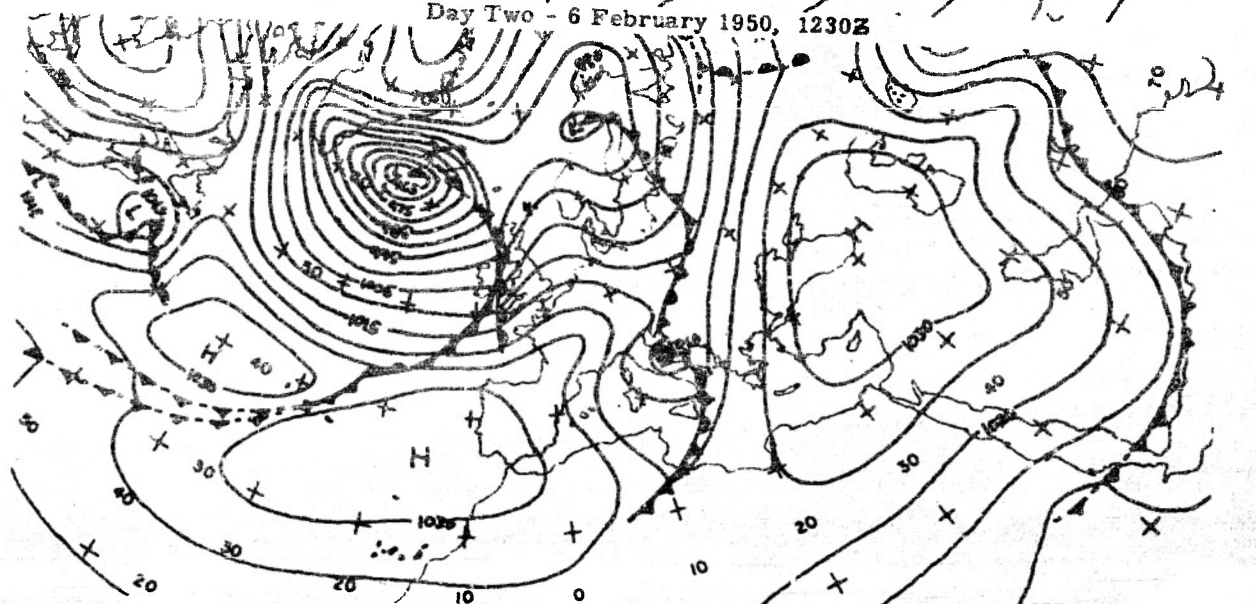
Day Three - 7 February 1950, 1500Z

CASE NO. 14
Surface Charts

Case 14 Summary with Day One Prediction

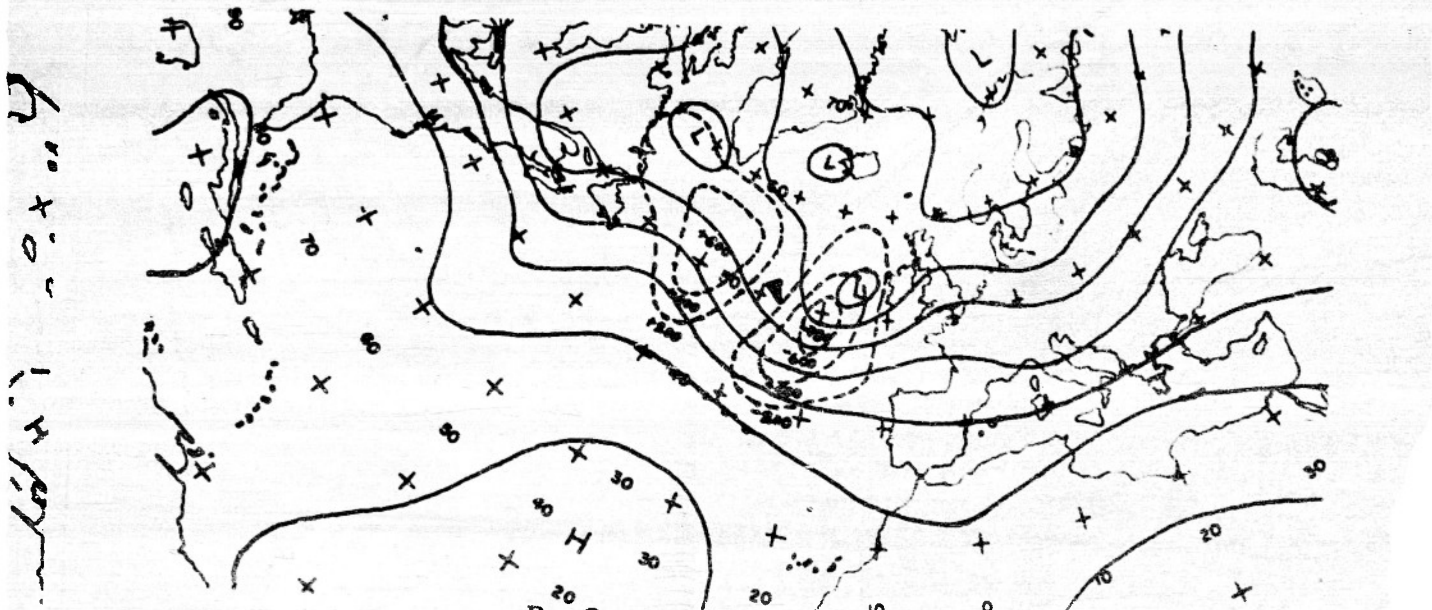


Day Two - 6 February 1950, 1230Z

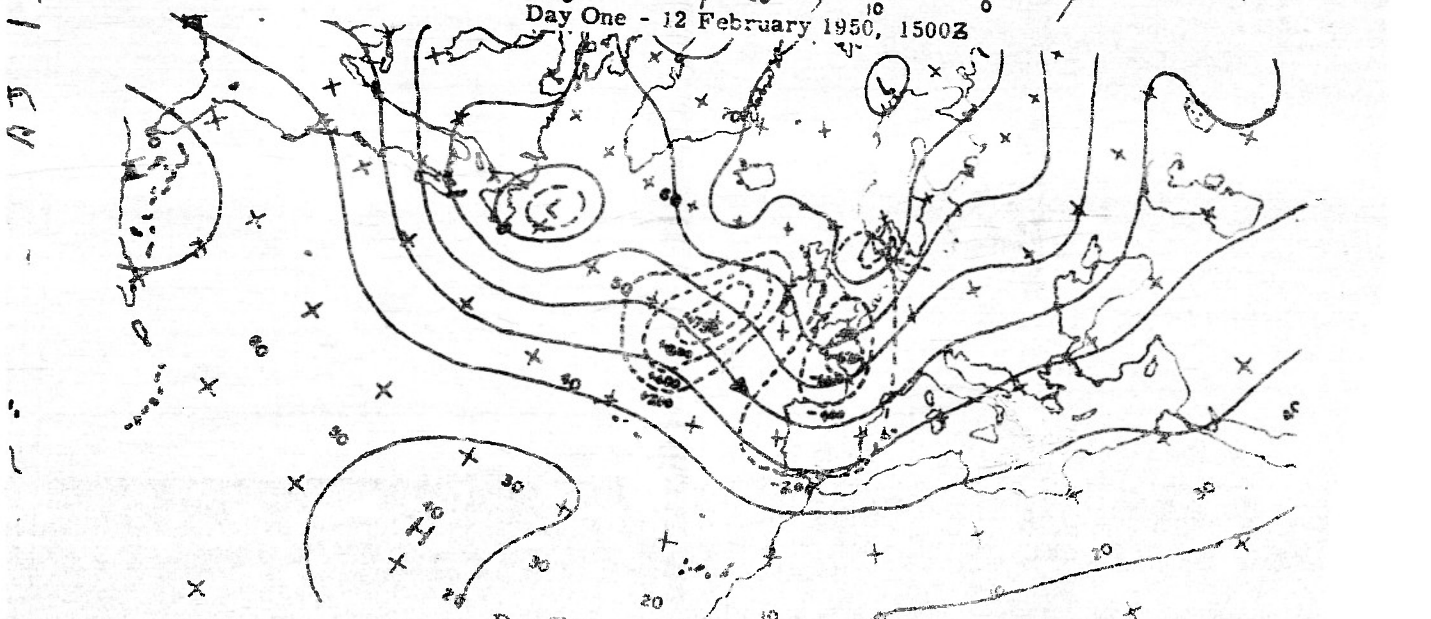


Day Three - 7 February 1950, 1230Z

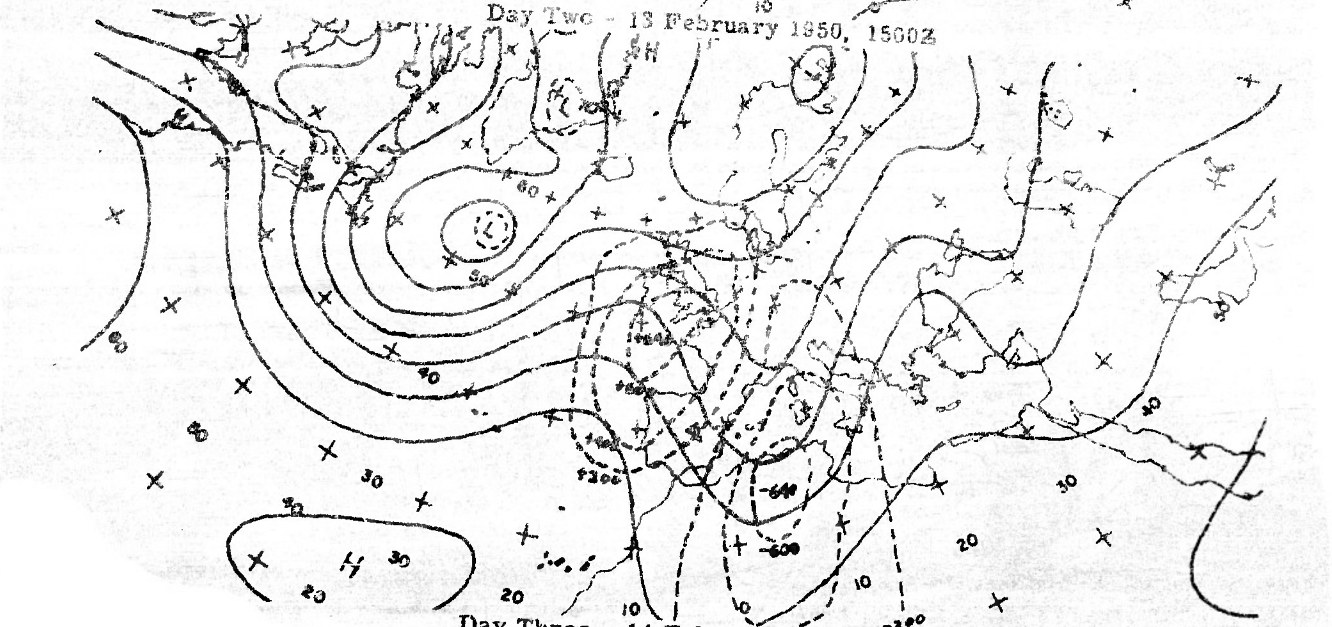
CASE NO. 15
500-Millibar Charts



Day One - 12 February 1950, 1500Z

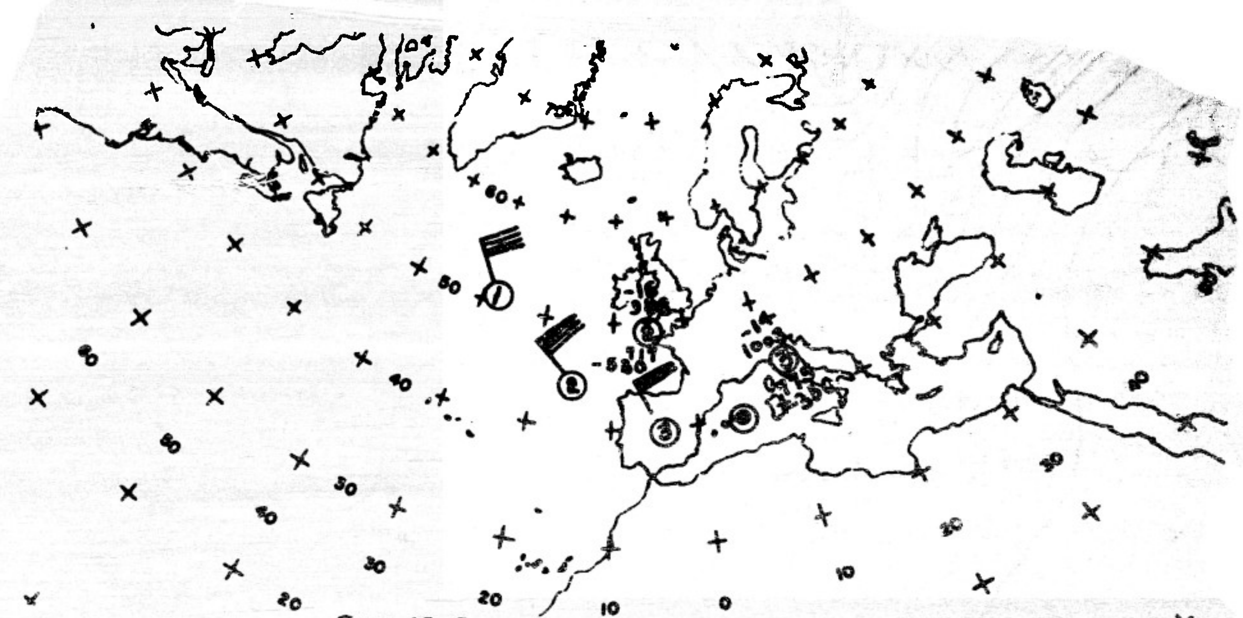


Day Two - 13 February 1950, 1500Z

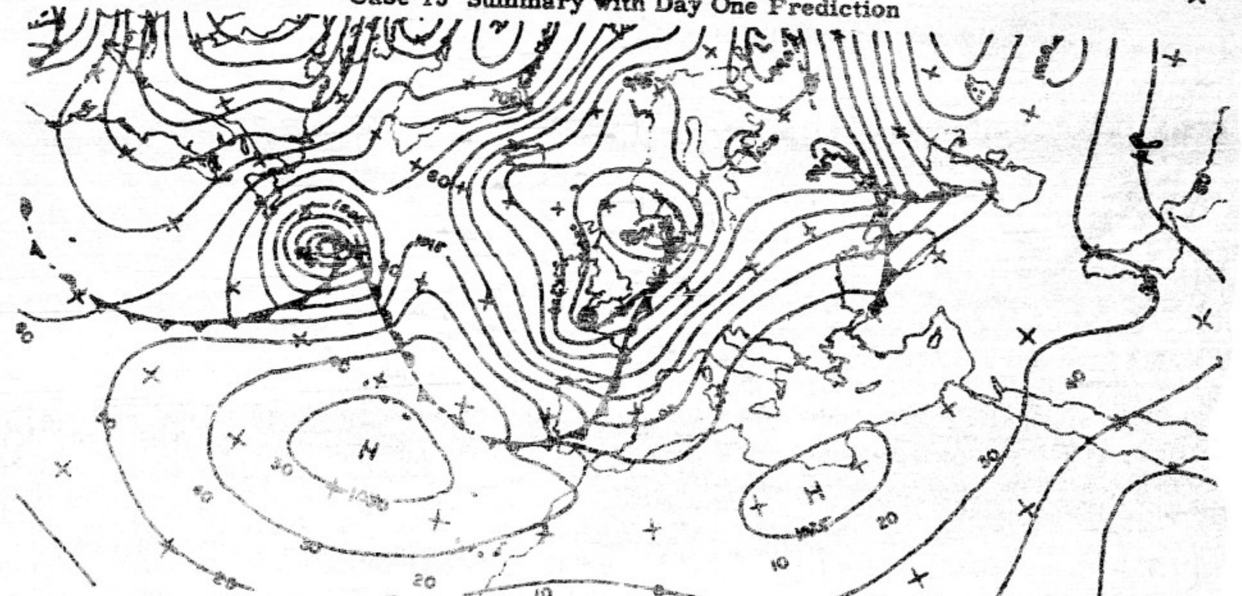


Day Three - 14 February 1950, 1500Z

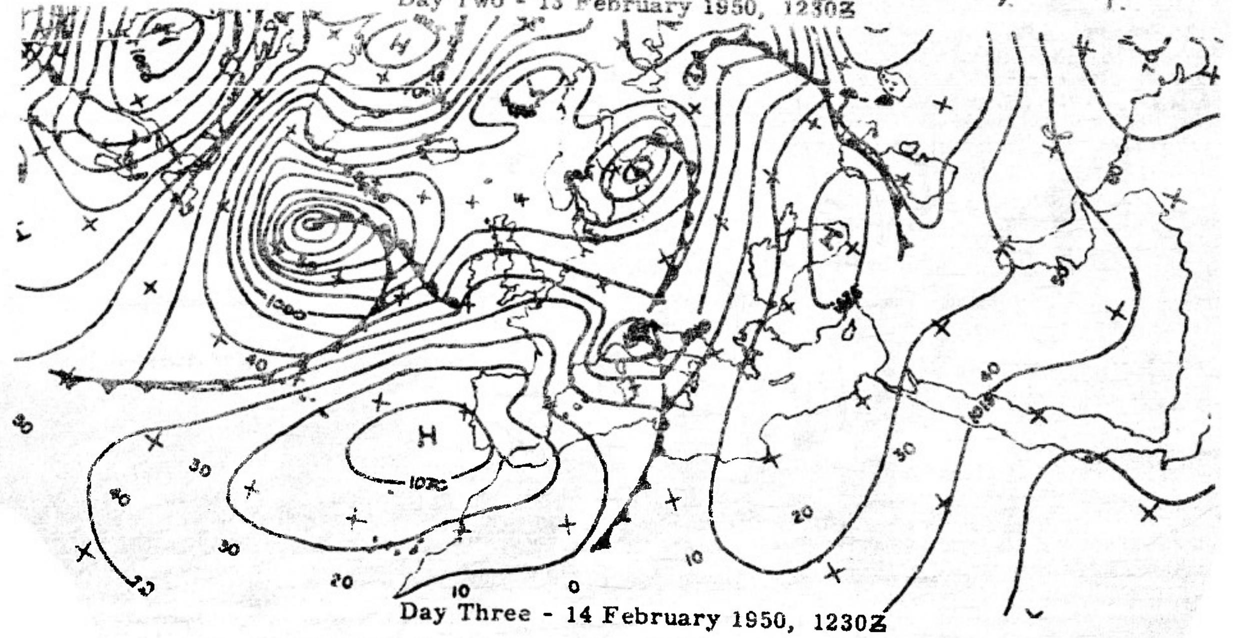
CASE NO. 15
Surface Charts



Case 15 Summary with Day One Prediction

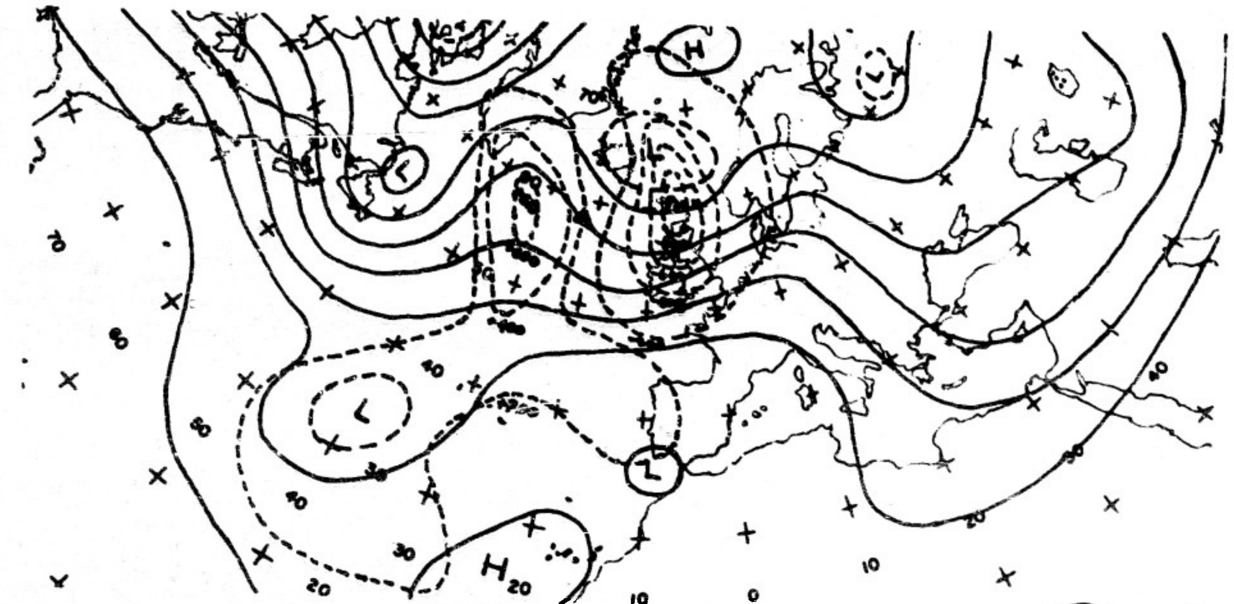


Day Two - 13 February 1950, 1230Z

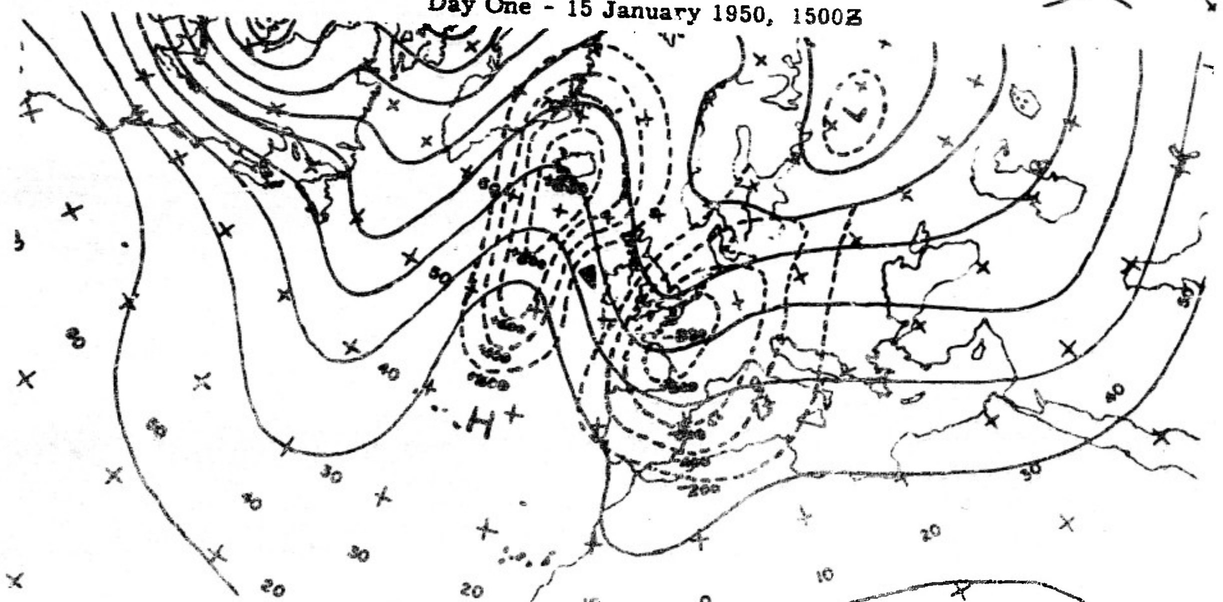


Day Three - 14 February 1950, 1230Z

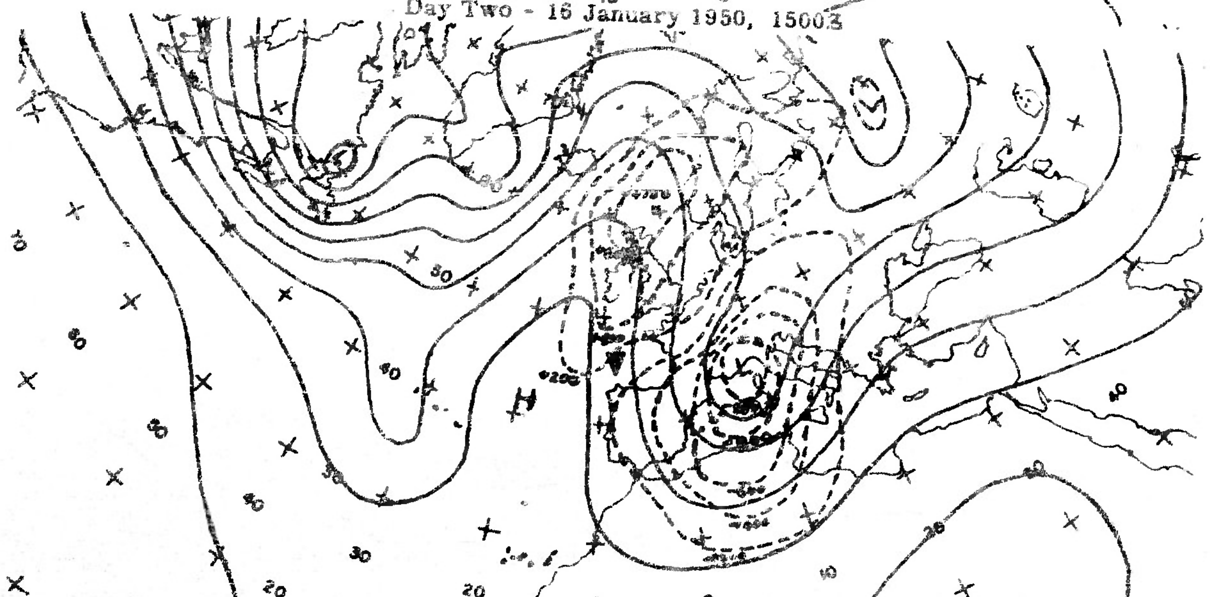
CASE NO. 16
500-Millibar Charts



Day One - 15 January 1950, 1500Z

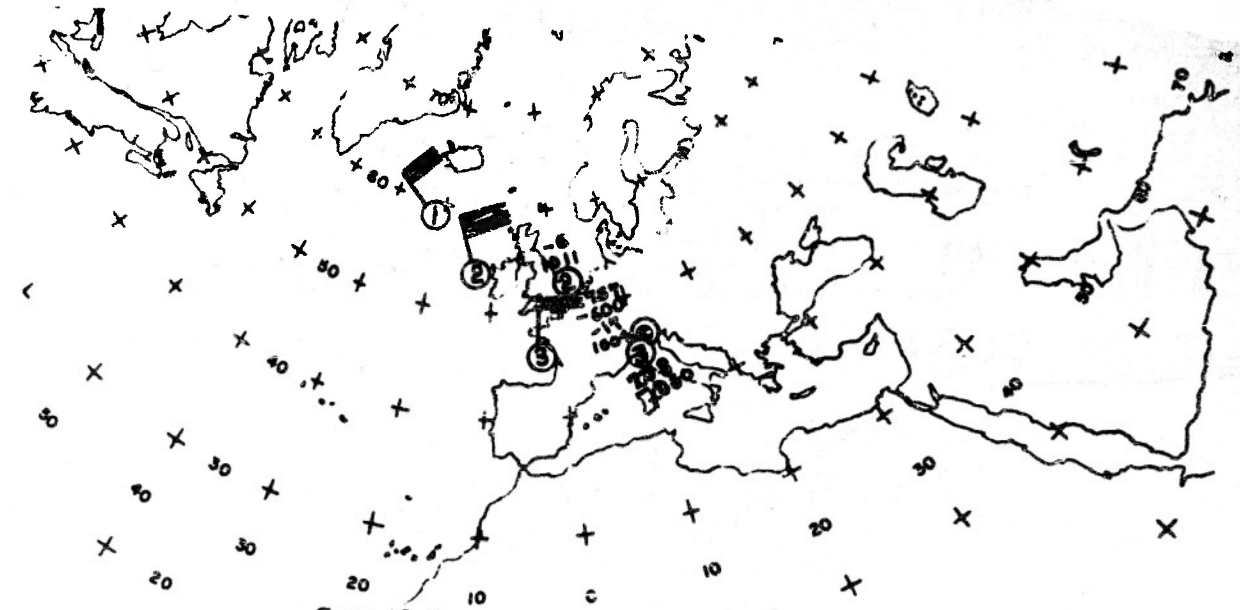


Day Two - 16 January 1950, 1500Z

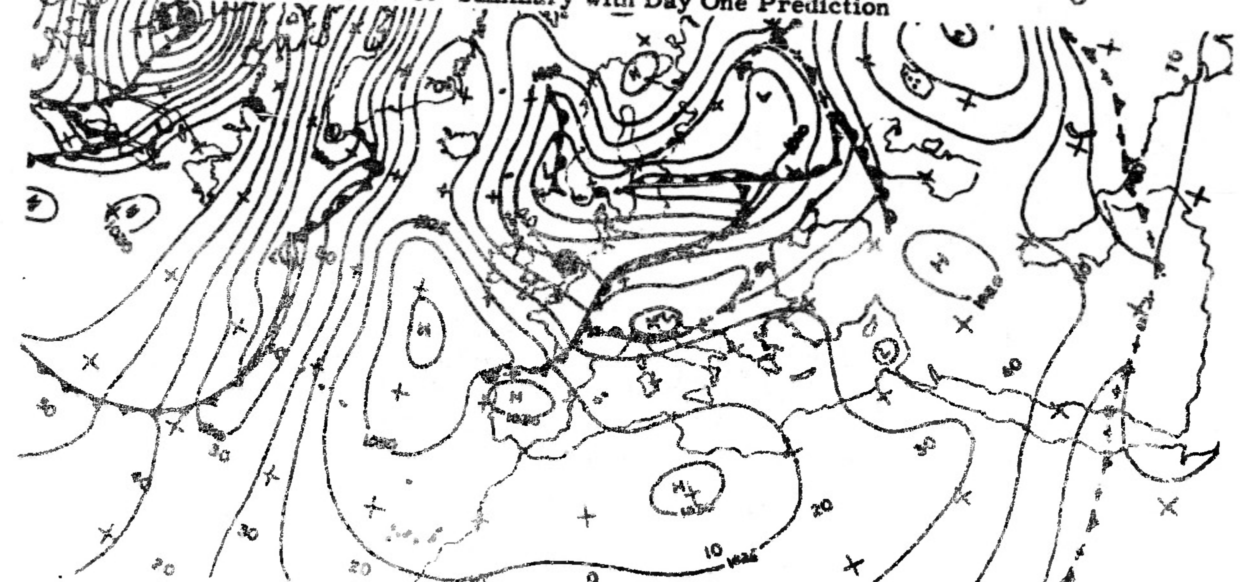


Day Three - 17 January 1950, 1500Z

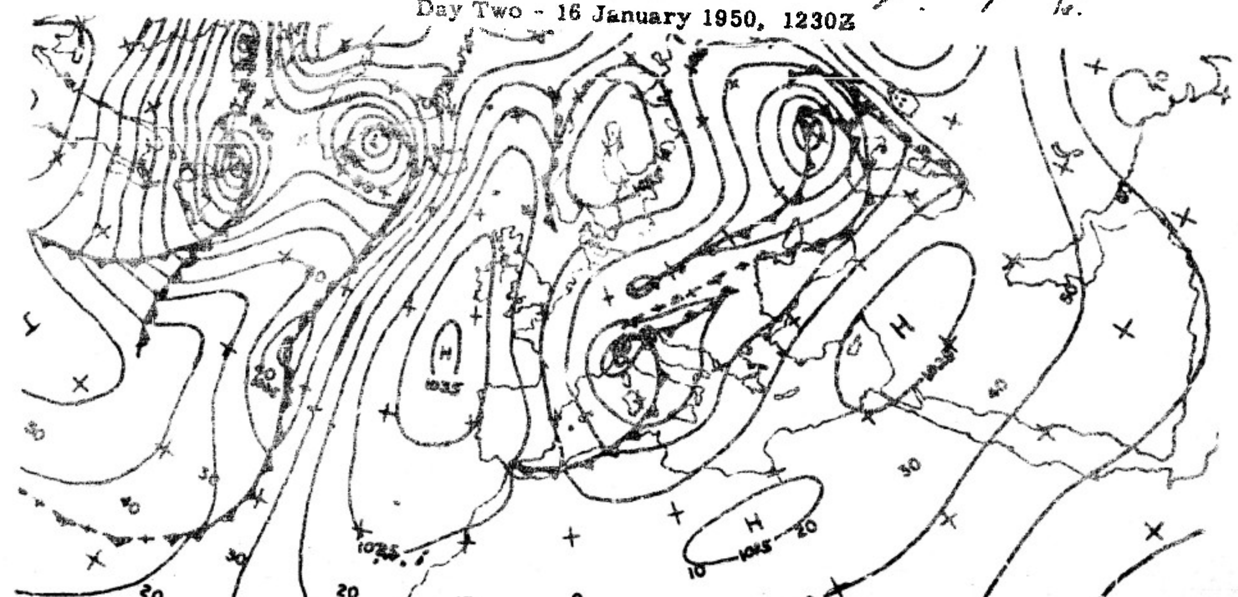
CASE NO. 16
Surface Charts



Case 16 Summary with Day One Prediction



Day Two - 16 January 1950, 1230Z



Day Three - 17 January 1950, 1230Z

CONCLUSIONS

1. Cyclogenesis over the Mediterranean is a different phenomenon from that over the United States, in that low-level (frontal) thermal contrasts are relatively unimportant, and the removal of mass largely takes place above the 500-mb level.

2. The occurrence or non-occurrence of cyclogenesis depends on the upper flow pattern and varies widely with different directions and types of 500-mb, large-scale flow.

3. Cyclogenesis following a westerly pattern is quite common and severe. It represents a change in regime, and this fact combined with meteorologists' usual reluctance to deal with the specific subject of predicting a new low makes the handling of this event more significant. The establishment of a northwesterly current following the westerly pattern and the existence of a pair of moving isallobaric centers at 500 millibars establish conditions followed by cyclogenesis downstream.

4. As long as an upper low or trough at 500 millibars exists over the Mediterranean, it will be reflected in a low at the surface. The movement of the surface low is determined by the movement of the upper low.

5. It is important to note that the procedure which operates to result in cyclogenesis over the Mediterranean is essentially an extrapolative one. The required height changes are in existence for several days and develop regularly. This distinguishes the process from Bjerknes' dynamic instability in connection with a ridge (1). The predictors used here are more easily found than are some others, such as effects due to lack of balance between wind and gradient. These latter factors may well contribute in these cases of course, but their utility is more restricted.

6. As with any new forecast scheme, a forecaster should use it sparingly at first and on cases which rather completely fit the initial conditions. A knowledge of the normal appearance and behavior of 500-mb, 24-hr height changes is also necessary. This experience can be acquired by leafing through the books of historical 500-mb height changes (8) being prepared by Project AROWA or from an article by Wolff (7).

7. The results of these investigations show that a revision of method is required when a forecaster accustomed to the United States is transplanted to the Mediterranean. Also indicated is a fundamental difference in importance among the physical atmospheric processes in these areas. This may account for the fact that the European forecasting schemes, such as Scherhag's (6), are relatively unsuccessfuly in the United States.

FURTHER INVESTIGATION

The following lines of further investigation became apparent during this study.

1. A climatological-type study of the winds, clouds, precipitation, temperature and local winds attending the storms of the Mediterranean in each flow type. It is suggested that these patterns will differ markedly between the relatively stagnant lows of the blocking-type pattern and the moving storms following a westerly pattern. This investigation would require considerable synoptic data at a closer time interval than the 24-hr continuity of the historical maps.

2. It is possible that the timing of the cyclogenesis could be further refined by a study of synoptic charts at closer time intervals. The intensity of the cyclone might also be determined.

3. The cyclogenesis involved in the northwesterly and blocking patterns could be investigated, but the parameters required would be different from those employed in this study.

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6. SCHERHAG, R., Neue Methoden der Wetteranalyse und Wetterprognose. Berlin, Springer Verlag, 424 pp. (1948).

7. WOLFF, P. M., "Behavior of Twenty-Four Height Tendency Patterns at 500 Millibars" in Some Recent Developments in Synoptic Meteorology, Section IX. Norfolk (1952).

8. PROJECT APOWA, 500-Millibar Height Change Charts. Norfolk (1952).

* This report is not widely available. The same material is contained in "Some Forecasting Relationships between Upper-Level Flow and Surface Meteorological Processes" by Staff Meteorologists, Eastern Air Lines, Inc., to be published soon as an Air Force Geophysical Research Paper.